CHAPTER 2

MORPHOLOGY AND MOLECULAR CHARACTERISATION

2.1 INTRODUCTION

2.1.1 Taxonomy

Systematics and taxonomy are two closely related branches of science. Systematics deals with the reorganisation of evolutionary events of taxa and the results are shown in the form of trees (cladograms). Taxonomy is the branch of nomenclature, description and classification of organisms (Komarek and Beutel, 2006).

Conventionally morphological information has remained as the basis of odonate taxonomy. Especially wing venation was the focal point of most taxonomic works (Polhemus, 1997; Trueman, 1996; Carle and Kjer, 2002; Rehn, 2003; Bybee et al., 2008). Till the recent past, wing venation was a popular tool for odonate classification, and priority was given to morphological features more than any other sources of data (Fraser, 1957; Hennig, 1969; Hennig et al., 1981; Pfau, 1991; Trueman, 1996). Homoplasy is the main drawback of these characters. The reliability of plesiomorphic traits in classification is not sufficient. (Vick, 2000; Dijkstra and Vick, 2006). As wing venation is evolved many times, its effectiveness is also reduced. The convergence phenomenon raises challenges in a taxonomic grouping. Protoneurines and Disparoneurines were mistakenly grouped in some taxonomies due to reduced wing venation (Carle et al., 2008). Wing venation data often create misleading hypotheses because of the convergence. Members of Calopterygoidea possess dense patterns, but these are also seen in other damselflies. Many damselflies show sparse venation patterns similar to that seen in Coenagrionidae and Lestidae. The flight style also caused homoplasy in wing venation. Anal vein regions of dragonfly gliders have widened as an adaptation to decrease energy consumption (Corbet, 1999). So, these kinds of characteristics may mislead or complicate the taxonomic studies (Ballare and Ware, 2011).

For the assignment of an organism to a particular genus, only some basic systematic knowledge is considered. The requirement of thorough knowledge of phylogenetics is generally ignored. New species descriptions based on poorly developed species concepts may result in misleading conclusions. Certain variations possessed by existing species may be wrongly identified as features of new species (Komarek and Beutel, 2006).

The inadequacies of morphology-based classification was revealed by modern research. The scarcity of taxonomic experts and the vast diversity of insects make the species identification and description complicated. The advent of integrative taxonomy has alleviated the problem to some extent. It is the application of data from different sources, i.e. genetic, morphological geographical and ecological, to make the species description and identification more accurate. The application of molecular techniques is an efficient and convenient method among the different approaches of integrative taxonomy (Wang et al., 2016). Although odonate systematics has a long history, relevant improvements in this field have occurred through molecular phylogenetic studies (Ware et al., 2007; Fleck et al., 2008; Dijkstra et al., 2014; Khelifa et al., 2017).

Despite the large size and noticeable colours, studies on odonate diversity and taxonomy are not easy as we think. The larval stages and presence of cryptic species remain huge hindrances in exploring odonates. Although lots of studies have been conducted on Odonates, most of them were confined to adults, particularly to their flying period (Bried et al., 2012; Solano et al., 2018; Galimberti et al., 2021, Maggioni., 2021). The data on other development stages are scarce. These gaps can be filled by an integrated approach of morphology and molecular technics. This method is well-accepted in other insect orders -Lepidoptera (Mikkola and Stahls, 2008), Coleoptera (Smith et al., 2006 a) and Hymenoptera (Polaszek et al., 2004). There are many successful works in odonates (Bybee et al., 2008; Caesar and Wenzel., 2009).

2.1.2 Molecular Taxonomy and DNA Barcoding

Precise identification of taxa and reliable assessment of biodiversity is still a challenging field of biology. The high diversity of insects always makes taxonomic studies complicated. Molecular methods alleviate this problem by recognising the interrelationship between different insect taxa through the proper understanding of variations and similarities along with evolutionary descriptions. Various molecular markers are used for this according to the nature of the study. Analysis using molecular markers can precisely discriminate between adult and larval forms, males and females, individuals of different castes in social insects and polymorphic individuals (Danforth et al., 2005).

For the assignment of organisms in higher taxa, a strong phylogenetic concept is inevitable. This led to the advent of evolutionary taxonomy, in which phylogenetic relationships are used as the basis for classification (Mayr, 1981). Classifications without the involvement of phylogeny fail to connect with historic evolutionary processes and are not confirmable. Evolutionary taxonomy is always predictable (Komarek and Beutel, 2006).

The application of molecular techniques in systematics evolved as additional information to increase the accuracy of traditional methods. But in some cases, molecular taxonomy has failed to synchronise with traditional taxonomy (Misof et al., 2001; Saux et al., 2003). While certain works agree with the traditional taxonomies (Kjer et al., 2006; Dijkstra et al., 2007; Ware et al., 2007; Bybee et al., 2008; Carle et al., 2008; Ballare and Ware, 2011).

DNA barcoding is a method of application of a short standardised gene sequence in species identification (Hebert et al., 2003). It varies from molecular phylogeny in that the primary purpose is to identify an unknown sample in terms of a known classification rather than to determine classification. DNA barcoding eliminates the requirement of taxonomic experts in identification to some extent. For animal DNA barcoding, COI gene is conventionally used. Its increased insertion-deletion rate and nucleotide substitution rate are suitable for distinguishing cryptic species. Universal primers of COI are robust. DNA barcoding requires databases having sequences of almost all species. Any specimen can be identified by DNA barcoding; for this, the specimen is sequenced first and compared with the sequences that exist in the database. (De Mandal et al., 2014). There is a considerable difference between DNA taxonomy and DNA barcoding. In DNA taxonomy, evolutionary species concepts are implemented for the portrayal and confinement of species, while the latter emphasises sequence similarity for deducing species circumscription (Vogler and Monaghan, 2007; Rach et al., 2008). DNA barcoding is the most suitable method for species identification. But for species discovery, implementation of DNA barcoding alone is not appropriate (Vogler and Monaghan, 2007). For this purpose, DNA barcoding should be used with additional data to form an integrated taxonomy (Rubinoff, 2006; Rach et al., 2008). The significance of DNA barcoding in the identification of organisms is well proven today. Use of short DNA sequences of particular regions called marker genes in barcoding has resolved

many current problems like confirmation of certain specimens into species, assignment of different species into higher taxa like genus, subfamilies and families and identification of cryptic species (Hebert et al., 2003; Smith et al., 2006 b). The complete database for CO I identification will definitely be a solution for the identification problems facing today (Hebert et al., 2003)

However, molecular identification techniques also face some problems. Sequence submission of wrongly identified specimens to the public databases is the major problem. These kinds of practices diminish the efficacy of the molecular approach and make the species delineation more complicated (Vilgalys, 2003; de Mendonca et al., 2011). The importance of specialised taxonomists is not reduced completely, as the reference databases require precisely identified sequences. Only with error-free databases, the accuracy of DNA based identification possible (Salvi et al., 2020). The use of holotype for DNA extraction and sequencing is a solution to this problem but it is not practical in all cases as the holotype is preserved for future reference or maybe obsolete (Wang et al., 2016).

2.1.3 Molecular Markers

The search for the most suitable DNA marker gene has still not ended. The mitochondrial DNA and nuclear rDNA are consistently sequenced in insect systematics. Gene sequences showing faster evolution are essential for analysing recent divergences. In contrast, deep relationships can be studied by conserved gene sequences (Chippindale, 1999). Although many marker genes are available today, no single gene exists that comprises all the essential qualities of an ideal marker gene. For example, ribosomal genes are far better than protein coding genes in the case of informative sites, but the alignment of these genes(ribosomal) is not easy (Cruickshank, 2002). The currently using marker genes come under the following categories.

a) Non-coding regions

Non-coding regions are suitable for species level studies, especially for closely related species, due to their high evolutionary rate. The regions coming under this category are control region of mitochondrial genes, introns and ITS regions of nuclear genes (Zhang and Hewitt, 1997). ITS1 and ITS2 (first and second internal transcribed spacer region of the nuclear ribosomal gene cluster) are commonly used

markers under this category. Since these regions are spliced out after transcription and have no other functions these are under weak selection pressure and have increased substitution rate. Because of these characteristics, ITS markers are generally used for intraspecific studies or studies of closely related species (Weekers et al., 2001; Cruickshank, 2002; Hovmoller and Johansson, 2004; Dumont et al., 2005, Kiyoshi and Sota, 2006).

b) Mitochondrial markers

There are certain qualities of mitochondrial DNA that make it a popular marker gene for phylogenetic studies. The mitochondrial genes are maternally transmitted and the rate of mutation is very high due to a weak repair system and also have conserved regions (Brown et al., 1979). These features are advantageous in the development of universal primers. The different regions vary in evolutionary rate and the increased copy number facilitates trouble-free isolation from degraded or scanty samples. The absence of recombination and rarely occurring gene rearrangements are the other advantages of mtDNA in phylogenetics. Sometimes nuclear mitochondrial DNA is formed when the mtDNA sequence invades into nucleus this sequence can be utilized for distinguishing between insect species (Richly and Leister, 2004; De Mandal et al., 2014). These genes are known as mitochondrial pseudogenes or numts (nuclear mitochondrial DNA). Certain studies have reported that these genes may interfere during amplification and sequencing and lead to inaccurate results (Cruickshank, 2002).

Mitochondrial genome of animal phyla is a double-stranded molecule enclosing 37 genes of large and small subunit ribosomal RNAs, 22 tRNAs for the translation of the protein coding genes and 13 protein coding genes required for oxidative phosphorylation process. A regulatory component, AT rich region significant in the initiation process of translation and replication is also present. The crucial mitochondrial genes are highly conserved in animals. Yet insects are exceptional and show variability among different orders. The two kinds of mitochondrial genes, the ribosomal and the protein-coding genes are used for phylogenetic studies (De Mandal et al., 2014).

The ribosomal RNA genes seen in insect mitochondria are, 12S rDNA and 16S rDNA. Internal transcribed spacers are not present between these genes. There

are 13 mitochondrial protein coding genes seen in insects. According to Zardoya and Meyer (1996), based on the effectiveness in phylogenetic studies these genes can be grouped into three:- good performers (ND4, ND5, ND2, COI and COII), medium performers (COB, COIII, ND1 and ND6) and poor performers (ATPase 6, ND3, ATPase 8 and ND4L).

Cytochrome oxidase subunit I (COI) is the most accepted marker gene. Cytochrome c oxidase is a crucial enzyme of mitochondrial electron transport system. Three genes are coding for the cytochrome oxidase subunit of mitochondria. Among these COI is the biggest one and is 894bp long approximately. COI and COII are widely used in the resolution of a wide range of taxonomic levels in insects from species level to families or orders. Different regions of COI are sequenced for various studies (De Mandal et al., 2014). The evolution of COI is slower than other protein coding mitochondrial genes (Patwardhan et al., 2014). 658 bp at the 5' end of Mitochondrial cytochrome c oxidase subunit I gene has been widely used (Maggioni et al., 2021). The next most frequently used gene sequences are 16S and 12S rRNA (Caterino et al., 2000; Misof et al., 2000; Kambhampati and Charlton, 2002; Saux et al., 2003). CO II is widely used and homologous sequences of almost all insect orders are obtainable in databases. Works based on COIII, NADH dehydrogenase 1 (Rach et al., 2008), ND2, ND4, ND5 and cytochrome b are not so common (Caterino et al., 2000).

12S rDNA is suitable for distinguishing higher level taxa like phyla as it is highly conserved (De Mandal et al., 2014). 16S rDNA is less conserved than 12S rDNA and it can be used for the classification of genera or families. The percentage of conservation among mitochondrial genes varies in this order: 12S rDNA> 16S rDNA> Cytochrome b> control region (CR). When moving from 12S rDNA to CR variability increases (Arif and Khan, 2009). Chippindale et al. (1999), Artiss et al. (2001), Lin et al. (2010), Yong et al.(2016), Zhang et al. (2017) and Cai et al. (2018) are relevant studies using mitochondrial marker genes.

c) Nuclear ribosomal genes

Ribosomal RNA is ubiquitous and comprises both highly conserved and variable regions and it is an appropriate tool for phylogenetic studies. Ribosome is composed of ribosomal RNAs and proteins. Ribosome have 2 subunits- a small subunit (SSU)

and a large subunit (LSU) in all organisms. In eukaryotes the SSU comprises a single RNA- 18S rRNA and LSU consists of three RNA species viz. 5S, 5.8S and 28S rRNAs. As the evolution of rRNA genes is slower when compared to that of the protein encoding genes, rRNAs are the right tool for studying distant relationships (Moritz et al., 1987; Patwardhan et al., 2014). 18S and 28S rRNAs are considered as the robust tool for analyzing deeper relationships (Cruickshank et al., 2002, Dumont et al., 2010).

Nuclear protein-coding genes also used for resolving phylogenies. Paralogy is the main problem with these genes. Duplications frequently happen and the probability of sequencing same copy of the gene in all taxa is low (Cruickshank et al., 2002). From this category of genes Elongation factor 1 alpha (EF1α) is generally analyzed in insects. Because of the intron/exon structure nuclear genes are applicable in the resolution of low taxonomic levels too (Cruickshank et al. 2002). Nuclear protein-coding genes show different intragenic and intergenic substitution rates and are easy to align. Because of these advantages, these are also good tools for insect phylogeny (Friedlander et al., 1992; 1994; Danforth et al., 2005).

Although a variety of mitochondrial and nuclear DNA markers are currently used for phylogenetic analysis, it is very important to select appropriate marker genes for the study purpose. As the marker genes are different in various aspects like conserved regions a wrongly selected marker gene can mislead the result Sunnucks (2000). Therefore, proper planning is crucial for every molecular work (De Mandal et al., 2014).

2.2 REVIEW OF LITERATURE

Odonata is a relatively well studied order when compared to other insect orders. A great deal of literature on odonates is available worldwide today, handling various aspects. Some relevant works related to the current topic are discussed here.

2.2.1 Taxonomic works on odonates

Among the earliest literature on world odonata, book written by Tillyard (1917) describing the anatomy, morphology, embryology, taxonomy, geographical distribution and collection and preservation techniques still draws attention. Another detailed account on odonate behaviour, life cycle and ecology was provided by Philip S Corbet (Corbet, 1962; 1980; 1999) enclosing reproductive behaviour, oviposition, stages of the life cycle, foraging behaviour, the physical environment, microhabitat and also interaction with human beings. A detailed description of North American odonates including classification and morphological features, collection and preservation techniques was prepared by Needham (1975) and he also published a book for the identification of odonates of North America (Needham et al., 2000). Dragonfly diversity of Great Britain and Ireland was studied by Hammond (1983). d'Aguilar, et al. (1986) provided a field guide to the odonates of Britain, continental Europe and North Africa. An elaborated description comprising evolutionary history, zoogeography, collection and preservation methods, breeding and rearing procedures, detailed checklist, descriptions and keys for larvae and adults of New Zealand dragonflies were prepared by Rowe (1987). A field guide was prepared by Watson et al. (1991) for the identification of Australian odonates. Dunkle (2000), prepared a field guide to the dragonflies of North America. An elaborated account encompassing all the aspects of dragonflies of Europe including a checklist of 124 species was published by Askew (2004). Theischinger and Hawking (2006) published a field guide to the entire species of Australia. A detailed record on odonates including conservation and a list of threatened species odonates of South Africa was published by Samways (2008). Dijkstra has made crucial contributions to the world odonate literature. Dijkstra and Kalkman (2012) reviewed odonate literature of Europe and generated summarized phylogenies. A detailed revision of the suborder Zygoptera was done, synonymized a number of well-established genera and described new families and subfamilies (Dijkstra and Kalkman, 2013; Dijkstra

et al., 2014). An elaborated description of odonate morphology and ultrastructure along with phylogeny, taxonomy, biology, ecology and behaviour, collection and sampling methods was done by Suhling et al. (2015). Garrison and Von Ellenrieder (2019) published of a list of synonyms of new world odonates as a revision of the old volume Garrison and Von Ellenrieder (1991). Two volumes of field guide to the dragonflies of Britain and Europe were also published (Dijkstra, 2006; Dijkstra and Schröter, 2020).

A detailed monograph on odonates of South Asia by Kalkman et al. (2020), presented a checklist of odonates of Bangladesh, Bhutan, India (including Andaman and Nicobar Islands), Nepal, Pakistan and Sri Lanka. The monograph documented 559 species of odonates including 251 single country endemic species. Most of the recent findings in odonate literature were compiled in the monograph. The species *Enallagma parvum* was placed under genus *Amphiallagma* (May, 2002). All the species of the genus *Cercion*, except *Cercion lindenii* was brought under the genus *Paracercion. Cercion dyeri* was synonymized to *Paracercion calamorum* (Weeker and Dumont, 2004). Specimens which were considered as *Ischnura aurora* from India are now regarded as *Ischnura rubilio* (Papazian et al., 2007). The genus *Onychargia* which was formerly placed under Family Coenagrionidae was shifted to Family Platycnemididae according to the studies of Dijkstra et al. (2014) and Orr and Dow (2015). *Gynacantha millardi* was wrongly considered as a synonym of *Gynacantha bayadera*. According to Priyadarshana et al. (2015), while *Gynacantha millardi* is distributed in India and Sri Lanka, *Gynacantha bayadera* is restricted to Northeast India. *Vestalis submontana* and *Vestalis nigrescens* were raised from subspecies level to species level. The three species *Vestalis nigrescens, Vestalis submontana* and *Vestalis apicalis* are endemic species. *Vestalis nigrescens* is endemic to Sri Lanka while the other two are endemic to India. *Vestalis submontana* is restricted to the Eastern and Western Ghats (Hamalainen, 2011; 2016). The South Indian species *Indosticta deccanensis* was formerly placed in genus *Platysticta* which is confined to Sri Lanka the morphological examination and molecular study confirmed the independent existence of genus *Indosticta* (Bedjanic et al. 2016). Among the two subspecies of *Lestes praemorsus* i.e. *Lestes praemorsus praemorsus* and *Lestes praemorsus decipiens*, only the latter one is seen in the Indian subcontinent. One more subspecies *Lestes praemorsus sikkima* was described from

Sikkim. The genus *Rhinocypha* was divided into *Aristocypha, Calocypha, Heliocypha* and *Rhinocypha*. *Libellago indica* was promoted to species level from the subspecies position of *Libellago lineata*. The former is endemic to peninsular India while the latter is widely distributed in southeast Asia (Hamalainen, 2016). Specimens which were considered as *Aciagrion hisopa* from India are now identified as *Aciagrion approximans* while *Aciagrion approximans krishna* is an endemic species of the Western Ghats and *Aciagrion approximans approximans* is distributed in northeast India (Joshi et al., 2016). *Ceylonolestes* is considered as the synonym of *Indolestes*; *Lestes umbrina* and *Lestes thoracica* are synonymized to *Lestes concinnus* (Dumont et al., 2017). *Anaciaeschna donaldi* and *Anaciaeschna kashmirense* are synonyms of *A. martini* (Conniff et al., 2019; Kalkman et al., 2020).

In India, the odonate studies were pioneered by Linnaeus (1758) through the description of the damselfly *Neurobasis chinensis*. But the site where he found the specimen was outside of India. In fact, *Rhyothemis variegata* was the first species described from India (Linnaeaus, 1763). Drury(1770; 1773), Fabricius (1775-1798), Selys-Longschamps (1840-1891) and Rambur (1842) were the initial contributors by whom several species from India were described (Subramanian and Babu, 2017).

Laidlaw's works in the Western Ghats and Eastern Himalayas (1914-1932) are noteworthy even in the modern world. F. C. Fraser can be considered a legend in this field because of his remarkable contributions, including publications (1918-1935) and a book series Fraser (1933; 1934; 1936). These books still have great value among odonate researchers and are being used as inevitable guides for identification. The earlier notable works in odonate literature are Singh and Baijal (1954), Singh (1955; 1963), Kumar (1971;1980;1984), Kumar and Prasad (1977), Lahiri (1977;1979;2003), Ram et al.(1983), Prasad and Ghosh (1988), Lahiri and Sinha (1991), Srivastava and Sinha (1993), Ram and Prasad(1999).

Odonate fauna of central India was well documented by Mitra (1986), who reported 11 new species. Further studies recorded 39 species from Central India (Mitra, 1988). A checklist of Indian odonate species with larval description was prepared by Prasad and Varshney (1995) with an allusion on *Epiophlebia laidlawi.*

Mitra recorded odonate fauna of different states of India such as 69 species from Orissa (Mitra, 2000), 92 from Arunachal Pradesh (Mitra, 2006), 13 species from Rajasthan (Bose and Mitra, 1975) and 32 species from Nicobar islands (Mitra, 2002 a). Mitra (2002 b) prepared list of endemic odonates of India. The high rate of endemism is observed in India due to its separation from the whole world by the Thar desert, Himalayas, oceans and seas. Odonate fauna of Rajastan Thar desert national park was studied by Prasad (2004). A systematic list and description of Indian odonates were prepared and presented a hand book (Mitra, 2006). 30 species of odonates were recorded from the moist deciduous forest surrounding Dholbaha dam, Hoshiarpur, Punjab, India (Sharma and Joshi, 2007). The impact of riparian land use on diversity and distribution of odonates was investigated by Subramanian et al. (2008). Andrew et al. (2008) prepared a field guide with detailed notes on 45 species, 32 species of dragonflies and 13 species of damselflies found in Nagpur. Subramanian (2009) published a checklist of Indian odonates. He has listed 463 species of odonates of India and has also given notes on species newly described, new species reported, species synonymized from India after 1995 and also a list of species removed from the checklist. 367 species of odonates were recorded by Mitra et al. (2010) from Eastern Himalayas of which 4 species are coming under the Threatened category. A review on the Indian species of the families Platycnemididae and Coenagrionidae was done by Mitra and Babu (2010). Rangnekar et al. (2010) recorded 66species of odonates from Goa with first records of 34 species from the state. The study raised the odonate diversity of Goa from 39 to 74. Through another study Rangnekar and Naik (2014), 13 more species were newly recorded from the same state with 5 endemic species. Thirty six species of odonates were recorded from Kanha National Park, Madhya Pradesh (Tiple et al., 2011). Odonate surveys were carried out at Tropical Forest Research Institute, Madhya Pradesh by Tiple et al. (2012) and reported 48 species of odonates referable to 32 genera of nine families including 8 new records to Madhya Pradesh. Tiple and Chandra (2013) documented 106 species of Odonata with 14 new records from Chhattisgarh and Madhya Pradesh. Studied the role of environmental variables such as canopy cover, area of water spread on transect, and altitude on the diversity and species composition of odonates. Studies conducted by Ashish D Tiple and Pankaj Koparde concentrated mainly on odonate fauna of Maharashtra. Tiple et al. (2013) documented 82 species from Vidarbha , Maharashtra by compiling survey results and other authenticated

records. Of the 82 species 13 were new to Vidarbha and 6 new records for Maharashtra. Seasonal distribution, habitat and significance of catchment land use on odonate diversity were studied by Kulkarni and Subramanian (2013). Tiple and Koparde (2015) compiled their survey results with previous records to generate a checklist of 134 species of odonates from Maharashtra. Checklist of odonates of India was prepared by Subramanian (2009) and Subramanian and Babu (2017). Subramanian and Babu (2018) compiled the previous works on the odonate diversity of the Himalayas and found 257 species including 23 endemics. Eastern Himalayas showed the highest diversity. The least diversity was observed in cold deserts. The study pointed out the threats faced by odonates in this region like dams, hydroelectric projects, agricultural activities, tourism and pollution. There is no recent reports of the living fossil *Epiophlebia laidlawi* from India. Subramanian and Babu (2019) described odonates of India including keys to adult and larval stages, habitat, life cycle, conservation status, economic importance and collection and preservation. Diversity and distribution along with the checklist of Northeast Indian odonates were recorded by Subramanian et al. (2020). By the study, it was revealed that streams and rivers of montane regions possess rich odonate diversity. Recently some new species descriptions and additions to the Indian Odonate checklist were done by Joshi and Sawant (2019; 2020), Joshi and Kunte (2017) and Joshi et al., 2016; 2017; 2020; 2022).

Odonate fauna of northeast India was explored by Prosenjith Dawn. A study was conducted in Kolkata and Howrah and documented 80 species of odonates, among them 4 are new records to West Bengal. The water bodies used for fish culture showed low odonate diversity due to manmade disturbances like the destruction of aquatic vegetation and the use of pesticides Dawn (2014). Joshi and Kunte (2014) documented 69 species from Nagaland including 43 new additions. Dawn, (2016) published a review work on larval studies in India and pointed out the insufficiency of larval and exuvial studies and also the need to improve such studies. He found that larval stages of only 20% odonates of India were brought under study. A bulk of data still remains unexplored. So, the studies on odonates should be extended not only to adults but also to larval stages and exuviae. A checklist comprising 239 species of 114 genera and 17 families was prepared from West Bengal (Dawn, 2021). 8 species were newly recorded from the state and two of them

Lyriothemis mortoni Ris, 1919 and *Cephalaeschna triadica* Lieftinck 1977, were the first records from India. He has also given brief notes on species wrongly identified and reported previously from West Bengal.

The Western Ghats, one of the 36 Biodiversity hotspots of the world, has high biodiversity and endemism. The Western Ghats, one of the most favoured places for diversity studies, and the exploration of odonate diversity of this region is still going on. The Western Ghats is always an ideal study location for odonate researchers. Odonates of western Ghats have been being studied by researchers and some prominent works such as Fraser, 1918 to 1936, 1938, 1939, 1946, 1953; Kimmins, 1958; Laidlaw, 1914-1917,1930; Lieftinck, 1960; Mitra, 1994; Prasad and Varshney, 1995; Tyagi, 1997 (Subramanian et al., 2018).

Subramanian (2007) studied about the endemic odonates of the Western Ghats and documented 68 species of endemics out of 176 odonates of the Western Ghats. He described the habitat distribution and conservation of endemic species of the Western Ghats. The seasonal and habitat distribution of odonate species at different land-use types in river basins of the Western Ghat region of Maharashtra was investigated by Kulkarni and Subramanian (2013). Subramanian et al. (2013) gave a note on the current distribution of the genus *Idionyx* of the WG and described a new species *Idionyx gomantakensis* from Goa(WG). Checklist of Odonates of Karnataka was prepared by Emiliyamma and Subramanian (2013) reported 137 sps of which 41 were endemics. Endemics are restricted to hill streams and forests of the WG. Koparde et al. (2014) documented 64 species of odonates from the WG region of Maharashtra, including 7 new records to the study area and 4 new records to Maharashtra. Adarsh et al. (2015) documented odonate diversity of the Chinnar Wildlife Sanctuary in the southern WG. Subramanian et al. (2018) studied the geographical distribution of odonates of different zones of Western Ghats comprising Coorg-Wayanad Nilgiri complex, Anamalai-Palani-Kodaikanal, Periyar and Aghastyamalai landscapes, prepared distribution maps and analysed the patterns of distribution of Western Ghats odonate species. Libellulidae, Gomphidae and Coenagrionidae are the predominating families of the Western Ghats. The representatives of these families occupy 58% of the total odonates species and 36% of endemics. 22 species of gomphids, 4 species of coenagrionids and only one species of libellulids were endemic to the study location. Most of the endemic

odonates are from Platystictidae, Platycnemididae, Gomphidae, Macromidae and Synthemistidae families. All representatives of the families Platystictidae and Chlorogomphidae and genera *Euphaea, Esme, Burmagomphus, Megalogomphus, Merogomphus, Microgomphus, Idionyx* are endemics to the Western Ghats. Hill streams and rivers of pristine riparian forests are the reservoirs of rich diversity and endemism. In contrast, low diversity and endemism can be seen in paddy field, marsh, lake and pond ecosystems. 2 species of genus *Euphaea* are recently described from the Western Ghats region of Maharashtra – *Euphaea thosegharensis* and *Euphaea pseudodispar* by Bhakare et al. (2021). First record of *Gynacantha khasiaca* from the Western Ghats was provided by Koli et al. (2021). The latest work revealed that the number of odonate species of the Western Ghats is 207, out of which 80 species are endemic (Nair et al., 2021).

In addition to the work of Fraser, the initial odonate studies of Kerala include the following works. Rao and Lahiri (1982) studied the odonate diversity of Silent Valley and New Amarambalam reserved forests and Mathavan and Miller(1989) conducted odonate survey of the Periyar National Park. Prasad and Kulkarni (2002) reported 34 specimens from Eravikulam National Park. A systematic account on 27 species of odonates of Thiruvananthapuram district was prepared by Emiliyamma and Radhakrishnan (2002). Odonate fauna of Kottayam District was recorded by Emiliyamma (2005). An authentic record of 31 species of odonates from Kottayam district was made by Emiliyamma (2005). 52 species of odonates were recorded from the Kerala Agricultural University (KAU) campus, Thrissur by Adarsh et al.(2014). The presence of agricultural fields and vegetated water bodies supported the rich diversity of this area. *Heliogomphus promelas* and *Indothemis carnatica* were also reported by this study which are belonging to the near threatened category in the IUCN Red List. The study also pointed out the significance of university campuses in the conservation of biodiversity. Emiliyamma and Radhakrishnan (2000; 2014) documented 39 species of odonates from Parambikulam wild life sanctuary. The photographic field guide by Kiran and Raju (2013) having records of 154 odonate species is still having great value among researchers. Varghese et al. (2014) recorded 82 species of odonates from the vicinity of Salim Ali Bird Sanctuary, Thattekkad including 21 endemic species and also some near threatened and vulnerable species. Endemic species were mostly confined to forested streams

and river ecosytems. Rivers and streams flowing through non forested habitats possessed less species richness and endemism. The study also revealed the occurrence of species coming under IUCN near threatened category (*M. hannyngtoni*) and vulnerable species (*P. deccanensis* and *P. sanguinostigma*). Forty-four odonate species were recorded from Kannur (Nair, 2014). Adarsh et al. (2015) reported 48species of odonates from Chinnar Wild Life Sanctuary, Idukki. Five different habitats were selected for study viz. scrub jungle, dry deciduous forest, moist deciduous forest, riparian forest and montane shola forest. The highest species richness was observed in the riparian forest. Two endemic species of the WG, *Protosticta gravelyi* and *Esme mudiensis* were also recorded. Three species namely *Gynacantha dravida*, *Esme mudiensis* and *Dysphaea ethela* which are categorized under Data Deficient IUCN Red List category were reported from Chinnar. Bose and Kakkassery (2019) documented the odonate diversity of Thrissur district. 59 species of odonates were recorded from Wayanad (Susanth and Anooj, 2020). Of these, four species are coming under IUCN data deficient category namely *Esme mundiensis*, *Pseudagrion indicum*, *Hylaeothemis indica* and *Macrogomphus wynaadicus*. 44 species of odonates were recorded from the Kole wetlands of central Kerala (Chandran et al., 2021).

Riparian diversity of odonates were studied by Vincy et al.(2016) at Meenachil river basin, Kottayam district and documented 36 species of odonates. Of these 9 species were newly added to the checklist of Kottayam district. Riparian odonate diversity of midstream Chalakkudy river was studied by Bose et al.(2021) and documented 25 species of odonates from the riparian habitat. Five endemic species were recorded of these *Pseudagrion indicum* is endemic to the WG and 4 species viz., *Vestalis apicalis, Libellago indica, Dysphaea ethela* and *Heliocypha bisignata* are endemic to India. The study pointed out the significance of abundant native riparian vegetation in odonate diversity and the adverse effects of habitat alteration and tourism activities on the existence of odonates. Although disasters like floods can cause an immediate drop in species richness and abundance, they will be bounced back to the normal level.

Recent studies added up the odonate diversity of Kerala to 174. Emiliyamma et al. (2012) *Microgomphus souteri* was recorded for the first time in Kerala. Emiliyamma et al. (2013) newly added *Lyriothemis acigastra* to the species list of

Kerala. *Protosticta ponmudiensis* was newly described from Ponmudi hills of the Agasthyamalai region of the WG region of Trivandrum district Kerala Kiran et al.(2015). *Protosticta monticola* was described from shola forests of Idukki district (Emiliyamma and Palot, 2016). Rangnekar et al.(2019) described a new species *Cyclogomphus flavoannulatus* from the Western Ghats region of Kerala and Goa. *Protosticta cyanofemora* was described from WG region of Kollam (Joshi et al., 2020). *Platylestes kirani* was described from the northern coastal region of Kerala (Emiliyamma et al., 2020). *Platylestes platystylus* was added to the checklist of Kerala (Rison and Chandran, 2020). *Protosticta rufostigma* from the Western Ghats region of Kerala (Sadasivan and Palot, 2021). Sadasivan et al. (2021) rediscovered *Anaciaeschna martini* from the WG region of peninsular India(also from Idukki dist.). *Bradinopyga konkanenesis* was recently reported from Kasaragod district of Kerala (Haneef et al., 2021). According to Nair et al. (2021) odonate list of Kerala is extended by the addition of species such as *Amphiallagma parvum*, *Ceriagrion chromothorax, Pseudagrion australasiae, Crocothemis erythraea, Protosticta sholai, Zygonyx torridus, Paracercion malayanum, Indothemis limbata, Indolestes pulcherrimus* and *Anax indicus* and reported the total species richness as 181. However, Gopalan et al. (2022) and Chandran and Sherif, (2022) confined the number of odonate species to 174.

Taxonomic characters of dragonfly exuviae can also be used for diversity studies of odonates. This method is advantageous because it does not harmfully affect the odonate population (Paul and Kakkassery, 2013; Adambukulam and Kakkassery, 2013).

2.2.2 Molecular taxonomy

Morphology is the cornerstone of taxonomy; however, sometimes, data from other areas of biology become inevitable for species identification and phylogenetic assessment. Identification based only on morphological features may lead to wrong classification (Herrera et al., 2010). The worldwide acceptance of integrative taxonomy has been increasing consistently because of the reliability contributed to taxonomy. It mainly integrates ecological, geographical, morphological, behavioural, developmental and molecular data to taxonomy to produce highly refined results Dayrat (2005). Since the development of molecular techniques,

molecular data have been regularly used in taxonomic works for species delineation and the construction of more reliable species hypotheses (Pimenta et al., 2019). Even though there are lots of studies by combining data from different branches with morphological data, application of molecular data is the most accepted, reliable and convenient method. The application of molecular techniques in phylogenetic studies has led to more reliable results.

While classical phylogeny depends on morphological traits for identifying the evolutionary relationships, application of nucleotide or protein sequences in analysing the relationships between organisms or genes is the base of molecular phylogeny (Patwardhan et al., 2014). The diversity is not confined to the morphological features but spread across the structural, biochemical and molecular frameworks. Organisms which show morphological resemblance may vary greatly in their biochemical and molecular characters. Both methods, i.e. classical and molecular phylogeny, have advantages and disadvantages and are equally significant as the morphological traits are determined mainly by the gene sequences. Thus, a combination of classical and molecular phylogeny yields a better resolution of relationships (Patwardhan et al., 2014). A perfect resolution of relationships occurs when molecular and morphological sources are congruent with each other and with geographical and ecological patterns (Dijkstra and Kalkman, 2012). Species identification becomes more accurate and objective when a combination of molecular based and traditional morphology based identification is applied (Tallei et al., 2017). Generally, when molecular and morphological pieces of evidence are in agreement, often in synchrony with geographical or ecological patterns, relationships are resolved most convincingly.

Molecular method of phylogeny is advantageous over morphological method because the former can be acquired easily. The gaps in fossil records can be filled by molecular method and is also free from sampling bias (Patwardhan et al., 2014). Among different molecular methods, the most accepted one is that which comprises DNA isolation, PCR amplification and sequencing and using these sequences for phylogenetic analysis. The identification based on marker genes becomes the most reliable method of taxonomy nowadays.

Molecular methods like DNA barcoding are accurate and nondiscriminatory tools for the assessment of taxonomy (Pfenninger et al., 2007). DNA barcoding is a highly efficient tool for taxonomic identification using a universal marker gene. Dr. Paul Hebert is called the father of DNA barcoding as he first applied this technique for taxonomic identification in 2003. This method has many advantages and the most important one is that the identification process is not affected by the stages of life cycle of organisms and the damage occurs for the specimen. The principle behind this method is comparing a particular marker gene sequence of unknown organism with the barcode library of the same gene for the precise identification of that organism.

Traditional methods of taxonomic identification of organisms, especially insects are time consuming and require the help of experts. Identification of immature or partially deformed forms is another hindrance in this field. Although the molecular methods are more accurate and reliable, the public databases (GenBank and BOLD) require more completely identified sequences. That means the sequences available in these databases are still inadequate, and many of the sequences are identified only up to the higher taxonomic ranks. The effectiveness of molecular taxonomy can be fulfilled only by the sufficient number of DNA barcode sequences identified up to the species rank (Porter et al., 2014).

Although species identification and species discovery are considered as the two important applications of DNA barcodes, only the former one is more appropriate. In species identification process DNA sequences are used. Make use of DNA sequences as markers of already described species is happened in the process of species identification. Instead of sticking on to a single species concept, DNA barcoding is congruent with any species concept that used for the establishment of a named species (Rach et al., 2008). Sometimes the traditional taxonomy fails to describe new species identified through molecular methods. Species discovery is more complicated and it is closely related to taxonomy. So, DNA barcoding alone cannot be used for this purpose. This is not a matter only for DNA barcoding but applicable to morphological, ecological and behavioural attributes. A single data type is not sufficient for species discovery process. It should be done with the aid of a species concept and verification is also needed (DeSalle et al., 2005; Rach et al., 2008). The genera *Stenocypha, Matticnemis* and *Spesbona* were newly identified by

molecular methods after that they were well described by morphological characters (Dijkstra, 2013).

A great deal of literature based on molecular taxonomy on odonates is available in the modern world. In the earlier time taxonomic studies were conducted based on single marker genes e.g., based only on 12S rRNA gene (Saux et al., 2003) or 16S rRNA gene (Misof et al., 2000). But presently a wide variety of marker genes are used both as single and in combination. The mitochondrial and nuclear marker genes have been predominantly used. The relevant works based on multiple marker genes are Chippindale et al. (1999) [mitochondrial Cytochrome b, Cytochrome oxidase II, and 12S ribosomal DNA]; Artiss et al. (2001) [mitochondrial COI and 16S rRNA]; Hasegawa and Kasuya (2006) [nuclear 28S rRNA and mitochondrial 16S rRNA]; Ware et al. (2007) [mitochondrial 16S rRNA and nuclear 28S rRNA]; Dumont et al. (2010) [nuclear ribosomal genes 5.8 S, 18S, and ITS1 and 2]; Froufe et al. (2014) [mitochondrial COI and nuclear ITS-1]; Guan et al. (2013) [mitochondrial COI and ITS]; Carle et al. (2015) [nuclear EF-1α and Histone H3 genes and mitochondrial COI and COII]. In other insect orders also the molecular identification methods are effective e.g., Insecta: Psocodea, based on 16S rRNA gene and COI gene (Yang et al., 2013).

2.3 MATERIALS AND METHODS

2.3.1 Study area

Selected habitats of Kerala state of India including high land, mid land and low land regions were selected for the present study. Kerala is located between 10.8505° N latitude and 76.2711° E longitude. Different types of habitats from 5 districts of central northern Kerala were randomly selected which include Wayanad, Palakkad, Thrissur, Ernakulam and Idukki (Plate 1). The observed habitats cover a variety of ecosystems including aquatic habitats near forests, agricultural lands including paddy fields and other human inhabited villages and urban areas, except the habitats of protected areas. Details of the locations selected for observation are given in Table 2.4.1. As the odonates can be easily found near water bodies the observations were mainly concentrated to the vicinity of water bodies including forest streams, rivers, ponds, paddy fields, lakes, canals, ditches and estuaries. The field study was continued in all seasons and the locations were randomly selected. Most of the observations were done between 9 AM and 1PM because majority of odonates are active during this period. Limited number of observations were done after 5 PM to observe the crepuscular species. Some of the observed habitats were given in Plate 2.

2.3.2 Collection, Identification and Preservation

Visual encounter survey method (Heyer et al., 1994; Arunima and Nameer, 2021) was used for the assessment of odonate species richness. The samples were collected using hand sweeping nets and kept in collection bottles. The samples were identified with the help of photographs, keys and descriptions given in the literature (Fraser 1933, 1934, 1936; Kiran and Raju, 2013; Joshi et al., 2022). After identification, the samples were kept in storage vials having 70% ethanol at 0^0C temperature in freezer. The vials were labeled with scientific name of the species, gender, date and location of collection.

2.3.3 Photographic documentation

The observed odonates were photographed using Nikon D3400 camera. Photographs showing the identification features clearly were documented.

2.3.4 Molecular Characterisation

Out of the total 71 odonate species observed, 34 species were selected for mitochondrial COI and nuclear 18S rRNA gene sequencing and for molecular

PLATE 1 - MAP OF KERALA SHOWING THE DISTRICTS SELECTED FOR THE STUDY

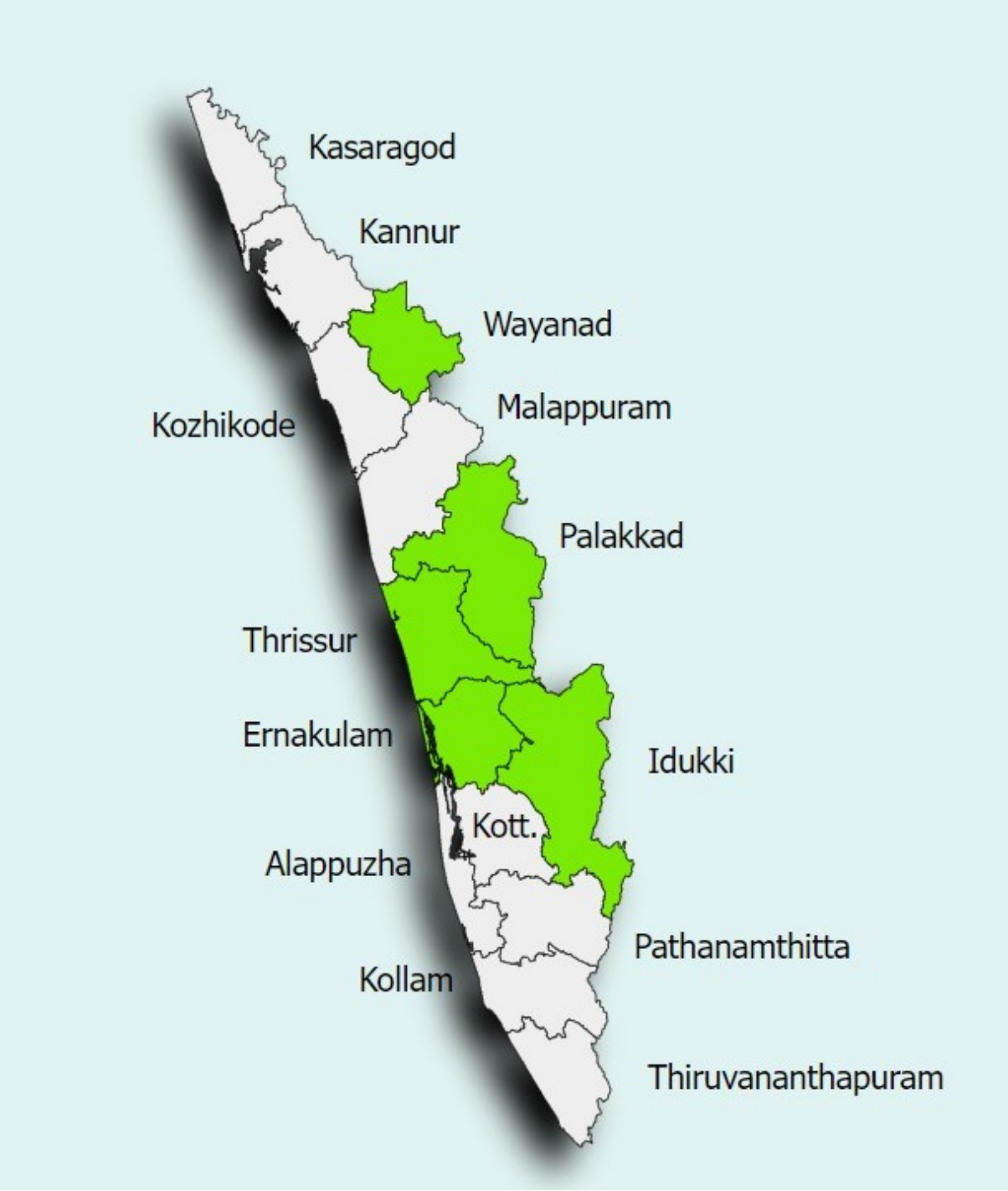

Figure 1A: Map of Kerala showing the districts selected for the study

PLATE 2 - STUDY LOCATIONS

Figure 2A: Mundakai (Wayanad)

Figure 2B: Ambalavayal (Wayanad)

Figure 2C: North Paravur (Ernakulam)

Figure 2D: Ottapalam (Palakkad)

Figure 2E: Kappithottam (Idukki)

Figure 2F: Chalakkudy (Thrissur)

phylogenetic analysis. The odonate species which were sequenced and analyzed in previous study in Kerala (Krishnan, 2018) were excluded from the current molecular study. From the remaining species, one or two representatives of each genus were selected. 34 species belonging to 28 genera, 10 families and 2 sub orders were selected for the present study.

2.3.4.1 Sample Preparation

For sample preparation, specimens kept in 70% ethanol were used. One of the thoracic legs of each dragonfly specimen and 3-4 thoracic legs of each specimen of damselfly were collected using forceps. Samples collected from each species were ground separately using mortar and pestle and used for DNA isolation and PCR amplification. The remaining samples were kept as voucher specimens at - 20°C in the repository of Laboratory of the Research and Post Graduate Department of Zoology, St. Thomas' College (Autonomous), Thrissur.

2.3.4.2 Isolation of genomic DNA

NucleoSpin® Tissue Kit (Macherey-Nagel) was used to extract genomic DNA from tissue samples.

1. Proteinase K (25 µl, 10mg/ml) and T1 buffer (180 µl) were added to the tissue kept in microcentrifuge tube (1.5ml), gently mixed and incubated for complete lysis in water bath at 56°C for 10 minutes.
2. RNase A was added (5 µl, 100 mg/ml) and incubated for 5 minutes at room temperature.
3. This was followed by incubation at 70^0C for 10 minutes after adding B3 buffer (200 µl).
4. Added 100% ethanol (210 µl) and mixed thoroughly.
5. Lysates were transferred to the NucleoSpin® Tissue column attached to a collection tube in the kit and centrifuged at 11000 x g for one minute.
6. The filtrate was discarded; to the remaining mixture added BW buffer (500 µl).
7. Then B5 buffer (600 µl) was added into the column and centrifuged at 13,500*g* for one minute.

8. The column was removed, transferred to a fresh receptacle, 50 µl of BE buffer was introduced to the centre of the column and centrifuged at 13,500 *g* for one minute.
9. DNA was stored at -20°C for further use.

2.3.4.3 Determination of quality of DNA

The quality of the extracted genomic DNA was assessed by agarose gel electrophoresis. The procedure adopted was as follows. 0.8 percent gel with long combed wells was prepared in 0.5X TBE, with 1.5 µl ethidium bromide (0.5µg/ml). One µl of 6 X gel loading buffer (bromophenol blue (0.25%) and sucrose (30%) in TE buffer pH-8.0) was mixed to 5 µl of DNA sample taken in a PCR tube and loaded into the large well created in the gel. Electrophoresis was done at 75 Volts using 5X TBE as tank buffer, until the migration of the dye was upto 2/3rd length of the gel. The gel was visualized and the image was recorded using Gel Doc EZ imager (Bio Rad).

2.3.4.4 Amplification of COI gene

Primers to amplify COI gene were selected from published reports of Folmer et al., 1994. The primers selected were custom synthesized from Sigma, diluted to a concentration of 10 pM/µl and used in PCR to amplify COI gene. The primer sequences and details were given in the Table 2.3.1. The PCR reaction mix and cyclic conditions used are given in Table 2.3.2 & 2.3.3. The PCR conditions were optimised by using different concentrations of reagents and different temperatures ranging from 54-66ºC. The PCR amplification was performed in a PCR thermal cycler (Veriti 96 well Thermal Cycler, Applied Biosystems).

Table 2.3.1 Details of primers used for the amplification of COI gene

Marker gene	Name of Primer	Direction	Sequence in 5' → 3' direction	Reference
COX1	LCO	Forward	GGTCAACAAATCATAAAGATATTGG	Folmer et al., 1994
	HCO	Reverse	TAAACTTCAGGGTGACCAAAAAATCA	Folmer et al., 1994

Table 2.3.2 PCR mix for the amplification of COI gene

Sl. No.	Constituents	Quantity
1	2X Phire Master Mix	5µL
2	Distilled water	4µL
3	Forward Primer	0.25µL
4	Reverse Primer	0.25µL
5	Template DNA	1µL
	Total	10.5 µL

Table 2.3.3 PCR conditions optimised for amplification of COI gene

Sl No.	Step	Temperature (^{0}C)	Time	No. of cycles
1.	Initial denaturation	98^{0}C	30 sec	1
2.	Denaturation	98 ^{0}C	5 sec	10
3.	Annealing	45 ^{0}C	10 sec	
4.	Extension	72 ^{0}C	15 sec	
5.	Denaturation	98 ^{0}C	5 sec	30
6.	Annealing	50 ^{0}C	10 sec	
7.	Extension	72 ^{0}C	15 sec	
8.	Final extension	72 ^{0}C	60 sec	1
9.	Hold	4 ^{0}C	∞	

2.3.4.4 Amplification of 18S rRNA gene

Primers to amplify 18S rRNA gene were selected from published reports by Giribet et al. 1996. The primers selected were custom synthesized from Sigma and were diluted to a concentration of 10 p*M*/µl. The primer sequences used for amplification of18S rRNA gene is listed in Table 2.3.4. The PCR was standardized

for different gradients of temperatures. The PCR conditions were optimised by using different temperatures ranging from 54-66ºC. The PCR amplification was performed in a PCR thermal cycler (Veriti 96 well Thermal Cycler, Applied Biosystems). The PCR reaction mix and cyclic conditions used are given in Table 2.3.5 and 2.3.6.

Table 2.3.4 Details of primers used for the amplification of 18S rRNA gene

Marker gene	**Name of the Primer**	**Direction**	**Sequence in 5' → 3' direction**	**Reference**
18S	1F	Forward	TACCTGGTTGATCCTGCCAGTAG	Giribet *et al*. 1996
	4R	Reverse	GAATTACCGCGGCTGCTGG	Giribet *et al*. 1996

Table 2.3.5 PCR mix for the amplification of 18S rRNA gene

Sl No.	**Constituent**	**Quantity (20 µL reaction)**
1.	5X Phire reaction buffer	4µL
2.	10mM dNTPs	0.4 µL
3.	Forward primer (10pM/ µL)	1µL
4.	Reverse primer (10pM/ µL)	1µL
5.	Template DNA	1µL
6.	DMSO	0.6 µL
7.	Phire Hot Start II DNA Polymerase	0.4 µL
8.	Distilled water	11.6 µL

Table 2.3.6 PCR conditions optimised for amplification of 18S rRNA gene

Sl No.	Step	Temperature (^{0}C)	Time	Cycles
1.	Initial denaturation	98	30Sec	1
2.	Denaturation	98	5 Sec	40
3.	Annealing	54	10 Sec	
4.	Extension	72	15 Sec	
5.	Final Extension	72	60 Sec	1
6.	End/Hold	4	∞	-

2.3.4.6 Agarose Gel electrophoresis

The amplified PCR products were checked in 1.2% agarose gel in 0.5X TBE buffer with ethidium bromide 1.5 µl (0.5 µg/ml). A volume of 5 µL of PCR product was mixed with 1µL of 6 X DNA loading dye and loaded in well along with 2-log DNA ladder (NEB) as the molecular standard. Electrophoresis was set at 75 V and after 45 minutes gel was documented using gel documentation system (Bio-Rad).

2.3.4.7 Sequencing

Representative PCR products were sequenced commercially at Rajiv Gandhi Centre for Biotechnology, Trivandrum by Sanger sequencing technique using automated DNA sequencer. In all cases both forward and reverse sequences were sequenced and final complete sequences were obtained in FASTA format along with respective ABI files containing chromatogram.

2.3.4.8 Sequence Analysis

After sequencing, the obtained sequences were processed using various bioinformatics tools. The reverse complement of the reverse sequence was generated using the Reverse complement bioinformatic tool. The reverse sequence was used along with the forward sequence in Emboss merger, which merged two overlapping nucleic acids into one (Bell and Kramvis, 2013).

The NCBI Basic Local Alignment Search Tool [BLAST] (Johnson et al., 2008) was used to check the sequence similarity of the resultant sequence with other sequences in the database. The COI sequences were translated to amino acid sequences by using the Expasy translate tool (Ramasubramanian, 2016) to identify the premature stop codons occurring through sequencing errors. The edited sequences were submitted to GenBank through the submission portal and received accession numbers.

2.4 RESULTS

Variety of habitats including paddyfields, ponds, streams, rivers, estuaries, canals, lakes, ditches and puddles of human occupied regions covering high land, mid land and low land were involved in the present study, except the habitats of protected areas and reserved forests. A total of 73 locations were observed for the study. The details of the study locations were given in Table 2.4.1.

Table 2.4.1 Details of study locations

Sl No.	LOCATION	LATITUDE	LONGITUDE	LOCATION TYPE
THRISSUR DISTRICT				
1.	Thrissur	10.5524° N	76.2272° E	Pond in urban area
2.	Chembuthara	10.5569° N	76.3169° E	Rocky stream
3.	Poomala	10.6096° N	76.2340° E	Dam reservoir
4.	Palakkal	10.4731° N	76.2125° E	Paddy field
5.	Kanimangalam	10.4861° N	76.2088° E	Pond with vegetation
6.	Nedupuzha	10.4867° N	76.1929° E	Kole field
7.	Kodannur	10.4665° N	76.1842° E	Kole field
8.	Pullu	10.4575° N	76.1523° E	Kole field
9.	Marottichal	10.4768° N	76.3435° E	Rocky stream
10.	Mannamangalam	10.4878° N	76.3435° E	Pond and stream
11.	Athirappilly	10.2908° N	76.5156° E	River near forest
12.	Vettilappara	10.2922° N	76.5149° E	River near forest
13.	Ayyampuzha	10.2279° N	76.6182° E	River near forest
14.	Thumboormuzhy	10.2956° N	76.4614° E	River near forest
15.	Nellayi	10.3941° N	76.2863° E	Pond near paddy field
16.	Chalakudy	10.3070° N	76.3341° E	Pond with vegetation
17.	Vellikulangara	10.3604° N	76.4115° E	Stream near rubber plantation
18.	Mala	10.2403° N	76.2631° E	Ditch near mangrove
19.	Poopathi	10.2188 °N	76.2649° E	Pond with minimum vegetation
20.	Kodungallur	10.2277° N	76.1971° E	Paddy field
21.	Valappad	10.3997° N	76.1160° E	Ditch and river
22.	Thoomanam	10.6678° N	76.2708° E	Waterfalls

23.	Kallamparachola	10.6254° N	76.2478° E	Waterfalls
24.	Varantharappilly	10.4255° N	76.3304° E	Stream near rubber plantation
25.	Elinjipra	10.3235 °N	76.3561° E	Pond and stream
26.	Kunnamkulam	10.6508° N	76.0694° E	Paddy field
27.	Chettuva	10.5242° N	76.0479° E	Mangove
ERNAKULAM DISTRICT				
28.	Moothakunnam	10.1902° N	76.2002° E	Ditch near estuary
29.	Sathar Island	10.1894° N	76.1914° E	Ditch near estuary
30.	North Paravur	10.1446° N	76.2273° E	Pond with shoreline vegetation
31.	Malayattur	10.1955° N	76.4968° E	River with shoreline plants
32.	Illithode	10.2032° N	76.5117° E	Vegetated ditch near brick factory
33.	Kodanad	10.1813 ° N	76.5150° E	Small stream with polluted water
34.	Kuruppampady	10.1112 ° N	76.5112° E	Vegetated small stream
35.	Nedumbassery	10.1679°N	76.3978° E	Ditches with shoreline grass
36.	Puthussery	10.1663°N	76.4097°E	Vegetated ditch
37.	Puthenvelikkara	10.1934°N	76.2456°E	Paddy field
38.	Kunnukara	10.1558°N	76.2902°E	Paddy field
39.	Thruthippuram	10.1975° N	76.2218° E	River
WAYANAD DISTRICT				
40.	Nellimunda	11.5397° N	76.1316° E	Rocky stream
41.	Elimbileri	11.5449° N	76.1060° E	Forest stream
42.	Cholamala	11.5397° N	76.1167° E	Rocky river
43.	Puthumala	11.5033° N	76.1431° E	Ditch with scarce vegetation
44.	Mundakai	11.4875° N	76.1556° E	Waterfalls
45.	Attamala	11.5021° N	76.1714° E	Stream near tea plantation
46.	Kuzhivayal	11.6003° N	76.14248° E	Ditch with shoreline plants
47.	Karapuzha	11.6181° N	76.1809° E	Dam reservoir

48.	Kalladi	11.5120° N	76.1330° E	Rocky stream
49.	Meppadi	11.5576° N	76.1317° E	River near tea plantation
50.	Kappamkolli	11.5636 ° N	76.1222° E	Ditch near banana plantation
51.	Palavayal	11.5727° N	76.1213° E	Ditch near brick factory
52.	Chembothara	11.5705° N	76.1258° E	Stream with thick vegetation
53.	Ambalavayal	11.6360° N	76.2037° E	Pond with emergent vegetation
54.	Palakkara	11.6430° N	76.3141° E	Tapioca plantation
55.	Kalpetta	11.5962° N	76.0868° E	Ditch
56.	Sulthan Battery	11.6629° N	76.2570° E	Tapioca plantation
57.	Thirunelli	11.9081° N	75.9971° E	Forest stream
58.	Vythiri	11.5517° N	76.0403° E	Small stream
59.	Choondale	11.5721° N	76.0580° E	River with grassy shore
60.	Moopainad	11.5359° N	76.1711° E	Ditch with shoreline plants
61.	Thomattuchal	11.5695° N	76.2197° E	Small stream
62.	Kuruva Island	11.8217° N	76.0922° E	Forest river & streams
63.	Panamaram	11.7381° N	76.0740° E	Paddy field
64.	Soochippara	11.5111° N	76.1643° E	Waterfalls
PALAKKAD DISTRICT				
65.	Govindhapuram	11.0083° N	79.4674° E	VegeTable plantation
66.	Parali	10.7977° N	76.5626° E	River
67.	Kollamkodu	10.7952° N	76.6630° E	Pond
68.	Vadakkumcherry	10.6008° N	76.4904° E	Grassland
69.	Ottappalam	10.7767° N	76.3759° E	Pond
70.	Puthuppariyaram	10.8597° N	76.6229° E	Waterfalls
71.	Nelliampathy	10.5349 ° N	76.6932 ° E	Vegetated streams
IDUKKI DISTRICT				
72.	Thodupuzha	9.8951° N	76.7237° E	Banana plantation
73.	Kappithottam	9.8892° N	76.7237° E	Paddy field

As a result of the study, a total of 71 species (33 species of damselflies and 38 species of dragonflies) were observed, belonging to 10 families and 43 genera. The systematic account of the observed species is given below.

2.4.1 Systematic account of order Odonata

Order: Odonata

Suborder: Zygoptera

Superfamily: Lestoidea

I. Family- Lestidae

1) Genus- *Lestes*

1. *Lestes elatus*
2. *Lestes praemorsus*

Superfamily: Platystictoidea

II. Family- Platystictidae

2) Genus- *Protosticta*

3. *Protosticta gravelyi*

Superfamily: Calopterygoidea

III. Family- Calopterygidae

3) Genus- *Neurobasis*

4. *Neurobasis chinensis*

4) Genus- *Vestalis*

5. *Vestalis apicalis*
6. *Vestalis gracilis*

IV. Family: Chlorocyphidae

5) Genus: *Heliocypha*

7. *Heliocypha bisignata*

6) Genus*: Libellago*

8. *Libellago indica*

V. Family: Euphaeidae

7) Genus: *Dysphaea*

9. *Dysphaea ethela*

Superfamily: Coenagrionidea

VI. Family: Platycnemididae

8) Genus: *Copera*

10. Copera marginipes

11. Copera vittata

9) Genus*: Onychargia*

12. Onychargia atrocyana

10) Genus: *Prodasineura*

13. Prodasineura verticalis

VII. Family: Coenagrionidae

11) Genus: *Aciagrion*

14. Aciagrion approximans krishna

15. Aciagrion occidentale

12) Genus: *Agriocnemis*

16. Agriocnemis keralensis

17. Agriocnemis pieris

18. Agriocnemis pygmaea

19. Agriocnemis splendidissima

13) Genus: *Archibasis*

20. Archibasis oscillans

14) Genus: *Ceriagrion*

21. Ceriagrion cerinorubellum

22. Ceriagrion coromandelianum

23. Ceriagrion rubiae

15) Genus: *Ischnura*

24. Ischnura rubilio

25. Ischnura senegalensis

16) Genus: *Paracercion*

26. Paracercion calamorum

27. Paracercion malayanum

17) Genus: *Pseudagrion*

28. Pseudagrion australasiae

29. Pseudagrion decorum

30. Pseudagrion indicum

31. Pseudagrion malabaricum

32. Pseudagrion microcephalum

33. Pseudagrion rubriceps

Suborder: Anisoptera

Superfamily: Aeshnoidea

VIII. Family: Aeshnidae

18) Genus: *Anax*

34. Anax guttatus

35. Anax immaculifrons

19) Genus: *Gynacantha*

36. Gynacantha dravida

37. Gynacantha millardi

Superfamily: Gomphoidea

IX. Family: Gomphidae

20) Genus: *Ictinogomphus*

38. Ictinogomphus rapax

X. Family: Libellulidae

21) Genus: *Acisoma*

39. Acisoma panorpoides

22) Genus: *Aethriamanta*

40. Aethriamanta brevipennis

23) Genus: *Brachydiplax*

41. Brachydiplax chalybea

42. Brachydiplax sobrina

24) Genus: *Brachythemis*

43. Brachythemis contaminata

25) Genus: *Bradinopyga*

44. Bradinopyga geminata

26) Genus: *Crocothemis*

45. Crocothemis servilia

27) Genus: *Diplacodes*

46. Diplacodes nebulosa

47. Diplacodes trivialis

28) Genus: *Hydrobasileus*

48. Hydrobasileus croceus

29) Genus: *Lathrecista*

49. Lathrecista asiatica

30) Genus: *Neurothemis*

50. Neurothemis fulvia

51. Neurothemis tullia

31) Genus: *Onychothemis*

52. Onychothemis testacea

32) Genus: *Orthetrum*

53. Orthetrum chrysis

54. Orthetrum glaucum

55. Orthetrum luzonicum

56. Orthetrum pruinosum

57. Orthetrum sabina

33) Genus: *Palpopleura*

58. Palpopleura sexmaculata

34) Genus: *Pantala*

59. Pantala flavescens

35) Genus: *Potamarcha*

60. Potamarcha congener

36) Genus: *Rhodothemis*

61. Rhodothemis rufa

37) Genus: *Rhyothemis*

62. Rhyothemis variegata

38) Genus: *Tetrathemis*

63. Tetrathemis platyptera

39) Genus: *Tholymis*

64. Tholymis tillarga

40) Genus: *Tramea*

65. Tramea limbata

41) Genus: *Trithemis*

66. Trithemis aurora

67. Trithemis festiva

68. *Trithemis pallidinervis*

42) Genus: *Urothemis*

69. Urothemis signata

43) Genus: *Zygonyx*

70. Zygonyx iris

44) Genus*: Zyxomma*

71. Zyxomma petiolatum

2.4.2 Detailed systematic account of order Odonata

Order Odonata

I. Suborder Zygoptera

The head of Zygopterans or damselflies is transversely elongated in shape. Eyes are well separated. All wings are almost identical in shape. During rest wings are kept closed over the abdomen and parallel to it. There are 2 pairs of anal appendages which are present at the end of the 10^{th} segment- a pair of superior anal appendages and a pair of inferior anal appendages. A highly developed ovipositor is seen in female.

Suborder Zygoptera is divided into 4 superfamilies – Lestoidea, Platystictoidea, Calopterygoidea and Coenagrionidea (Kalkman et al., 2020). In Kerala, there are 7 families coming under Zygoptera. Representatives of all families were recorded during the study.

1) **Family Lestidae** Calvert, 1907

The members of this family are known as spreadwings as they keep their wings wide open during rest. Damselflies having small to medium sized body. The colours on body are iridescent or non-iridescent. Most species move their abdomen up and down during rest.

Out of 12 species of 3 genera found in Kerala, 2 species belong to genus *Lestes* were recorded.

1. **Genus *Lestes*** Leach, 1815

They are small to medium sized damselflies. Petiolation starts just before the level of *ac*. The position of *ac* is about half way between two antenodal nervures. Pterostigma is twice in length than its breadth. Discoidal cells of fore and hind

wings are closely similar. Metallic markings on head, thorax and abdomen is present in some species.

2) **Family Platystictidae** Kirby, 1890

They are slender and long bodied damselflies. Generally black or brown coloured body having white or blue markings. Transparent wings with pointed tips. Length of abdomen is twice or more than twice of hind wing length.

All species of this family, found in Kerala are endemic to the Western Ghats. 12 species belonging to 2 genera are found in Kerala as representatives of this family. One species was recorded by the current study.

2. **Genus *Protosticta*** Selys, 1885

This genus comprises very slender elongated damselflies, known as 'reed tails' and they are found in untouched forest streams. Of the 11 representatives reported from Kerala, only one was recorded during the study.

3) **Family Calopterygidae** Selys, 1850

These are large sized and iridescent coloured damselflies also known as 'glories'. Head is broad and eyes are round and very prominent. Hindwings are broad and with rounded tips. Wings are transparent or opaque with iridescent colouration. Abdomen is more elongated than hindwing (Subramanian, 2008).

Out of 4 species of 2 genera found in Kerala, 3 species coming under both genera were recorded.

3. **Genus *Neurobasis* Selys, 1853**

In males, fore wings are transparent, hind wings are opaque and coloured with metallic blue or green. Pterostigma is absent. All wings are transparent and with false pterostigma in females. Only one species of *Neurobasis* is reported from India (Kalkman et al., 2020).

4. **Genus *Vestalis*** Selys, 1853

Wings are rounded at tips. Wings are transparent or with blackish brown tips. Pterostigma is absent. Discoidal cell has the same length of basal space and has a number of nervures. Legs are thin and elongated. Abdomen is long and has cylindrical shape. The ground colour of body is metallic blue or green.

4) **Family Chlorocyphidae,** Cowley, 1937

They are damselflies, also known as 'stream jewels' having small sized body, prominent bulbous eyes and protruding face. Thorax is short and stout. Wings are transparent or partially opaque with iridescent colours. Cylindrical shaped abdomen and shorter than hindwing. Forested streams are preferred breeding habitats.

Three species belonging to 3 genera are reported from Kerala. During the present study 2 species were recorded.

5. **Genus *Heliocypha*** Fraser, 1949

This is the genus of small damselflies with iridescent coloured wings. These are commonly found in forested streams (Subramanian, 2009). The genus *Heliocypha* has only a single representative in Kerala.

6. **Genus *Libellago*** Selys, 1840

Fore wings of males are black at the apices in most species of this genus. The end point of petiolation is proximal to the first antenodal nervure. *Riii* begins far distal to node. Mesothoracic triangle is reduced and without bright colours. Slender and elongated legs. Abdomen is considerably shorter than wings and tapering towards segment 10.

5) **Family Euphaeidae** Yakobson & Bainchi, 1905

Members of this family are having large body size and large round eyes. Wings are transparent, tinted with brown or having iridescent markings. Hindwings are broad and rounded and shorter than forewings. Length of abdomen is more than that of wings in males. In females it is shorter than wings or of the same length (Subramanian, 2008).

Four species coming under 2 genera are reported from Kerela out of them only one species was recorded by the current study.

7. **Genus *Dysphaea*** Selys, 1853

Wing petiolation is completely absent. Narrow and long pterostigma is present in wings. Thorax is robust. Anal appendages are longer than segment 10, simple and homogenous.

6) **Family Platycnemididae** Yakobson & Bainchi, 1905

They are small and slim bodied damselflies. The body is black in colour and marked with red, yellow or blue. Wings are transparent and narrow with rounded tips. Length of abdomen is more than that of hind wing (Subramanian, 2008).

In Kerala the representatives of this family are 16 species belonging to 9 genera. Four species of 3 genera was encountered during the study.

8. **Genus *Copera*** Kirby, 1890

Damselflies having small or medium size. Length of abdomen is less than twice the wing length. The 2nd segment of antennae is equal in length or more than 3rd segment. Transparent wings with moderately rounded tips. Anal appendages in males are less homogenous.

9. **Genus *Onychargia*** Selys, 1865

Small or medium sized damselfies with ground colour of black or bronzed purple and marked with citron yellow. Markings are absent in old adults. Short, broad and transparent wings. Pterostigma is half as long as broad.

10. **Genus *Prodasineura*** Cowley, 1934

This is the genus of slender, elongated black damselflies. Genus prodasineura has a single representative in Kerala, which is endemic to India.

7) **Family Coenagrionidae** Kirby, 1890

This is the largest family of damselflies in Kerala. The smallest damselflies in Kerala belong to this family. These are small to medium sized damselflies and found in variable non-iridescent colours. The wings are transparent with rounded tips. Abdomen is very slim and slightly longer than wings.

The representatives of this family in Kerala are found in 9 genera and 24 species. In the present study a total of 20 species of 7 genera were recorded.

11. **Genus *Aciagrion*** Selys, 1891

They are slender, small sized damselflies. Non metallic. The ground colour of body is blue or violaceous and have black markings. Wings are narrow and transparent. The size and shape of pterostigma vary in fore and hind wings. In forewings it is diamond shaped and has double the size of that in hindwings. Head

is narrow with triangle shaped or elongated postocular spots. Slim thorax and short legs. Anal appendages vary between species and very small sized.

12. **Genus *Agriocnemis*** Selys, 1877

These are very slender and smallest damselflies. Non metallic colours. Black with bluish markings or greenish or bluish with black markings and with orange coloured last abdominal segments. Pterostigma is small and diamond shaped, similar or dissimilar in fore and hind wings. Head is narrow and the frontal ridge is absent. Coloured postocular spots are present. Short and robust thorax. Slender and cylindrical abdomen is dilating towards last segments. Legs are short.

13. **Genus *Archibasis*** Kirby, 1890

These are slender medium sized damselflies. Colours are non metallic and bluish with black markings. Wings are narrow and transparent. Pterostigma is similar in all wings and subquadrate shaped. Head is small, postocular spots are present or absent. Thorax is moderately robust. Legs are short and robust. Superior anal appendages have the same length of segment 10. Rounded or slightly notched end. Inferiors are cone shaped and half the length of superiors.

14. **Genus *Ceriagrion*** Selys, 1876

Slender medium sized damselflies with non metallic colours. Generally, with ground colour yellow, olivaceous or orange. Wings are transparent with lozenge shaped, narrow pterostigma. Narrow head with a prominent frontal ridge. Postocular spots are absent. Long narrow thorax. Slender, cylindrical abdomen is twice the length of hind wings. Superior anal appendages are short and hook shaped. Inferiors are longer and conical in shape.

15. **Genus *Ischnura*** Charpentier, 1840

These are small, slender damselflies. Colours are non metallic. Generally blue or green with black markings. Females are polychromatic. Transparent wings and the pterostigma varies in shape and size in fore and hind wings. Head is narrow and the frontal ridge is absent. Postocular spots are present. Abdomen is robust and moderately short. Anal appendages vary greatly between species.

16. **Genus *Paracercion*** Weeker & Dumont, 2004

They are small sized slender damselflies. Colours are non metallic. Generally blue with black markings. Females vary from males in colour. Pterostigma is small and similar in all wings. Head is narrow and frontal ridge is absent. Coloured postocular spots are presents. Thorax is robust. Abdomen is slender and cylindrical slightly dilating on both ends. Anal appendages vary between species. Superiors are longer than inferiors.

17. **Genus *Pseudagrion*** Selys, 1876

These are slender and medium sized damselflies. Colours are non metallic. Generally bright bluish with black markings. Wings are transparent. Pterostigma is narrow, lozenge shaped and similar in all wings. Head is narrow and having coloured, triangular postocular areas. Slender thorax and abdomen. Anal appendages are variable. Superiors are forked or notched at ends and have same length or shorter than segment 10. Inferiors are shorter and conical in shape.

II. **Suborder Anisoptera** Selys, 1854

Head of Anisopterans or dragonflies is globular and compact. Eyes are confluent on vertex but in some genera they are separated. Wings are dissimilar in venation and shape. Hind wing is broad at the base. Discoidal cell is divided into two triangular cells- a superior hypertrigone and an inferior discoidal cell. Pterostigma is present and vary in length. Wings are kept horizontally perpendicular to the body or downwards during rest. Tenth abdominal segment has a pair of superior and a single inferior anal appendages.

In Kerala suborder Anisoptera is represented by 6 families viz. Aeshnidae, Gomphidae, Chlorogomphidae, Macromiidae, Corduliidae, Libellulidae and some species are considered *Incertae sedis* as it is not confirmed to which family they belong. Out of these representatives of 3 families were recorded during the study.

8) **Family Aeshnidae** Leach, 1815

Family of crepuscular or diurnal species. Dragonflies having large to medium sized body. Body colouration is non-iridescent. Eyes are widely contiguous at their inner margins. Transparent wings often lightly tinted with brownish yellow. The basal part of abdomen is swollen in most species.

In Kerala 9 species of Aeshnidae belonging to 3 genera are found (Nair *et al*. 2021). Out of them 4 species coming under 2 genera viz. *Anax* and *Gynacantha* were recorded during the study.

18. **Genus *Anax*** Leach, 1815

They are large sized dragonflies and robustly build body. Transparent wings with yellow or pale brownish tint partially. Large and globular head and the eye borders are widely contiguous. Occiput is small. Robust thorax and legs. Long and broad wings having pointed tips. Long narrow and braced pterostigma. Basal segments of abdomen are tumid and there is constriction at segment 3. Superior anal appendages are broadly lanceolate with rounded tips and have a small spine. Inferiors are shorter and quadrate shaped.

19. **Genus *Gynacantha*** Rambur, 1842

They are large sized and robust build dragonflies having crepuscular nature. Ground colour is dull brown or green generally. Head is large and globular in shape. Eyes are widely contiguous. Small thorax and short legs. Long, broad and transparent wings with close reticulation and the pterostigma is moderately long, narrow and braced. Basal segments of abdomen are tumid with or without constriction on segment 3. Long slender anal appendages and inferiors are narrowly triangular.

9) **Family Gomphidae** Rambur, 1842

Gomphids are large sized dragonflies. The body colour is generally black with yellow markings or yellow with brown or black markings. Wings are transparent. The last abdominal segments are enlarged to form a club shape. So, the dragonflies belong to this family is called as clubtails. Out of 22 species of 17 genera found in Kerala (Nair *et al.* 2021), 1 species was recorded by the present study.

20. **Genus *Ictinogomphus*** Rambur, 1842

They are large and robust bodied dragonflies. Black coloured body marked with citron yellow or greenish yellow. Large triangular head. Robust thorax and legs. Wings with close reticulation. Abdomen dialated at both ends and middle segments are narrow.

10) **Family Libellulidae** Leach, 1815

They are the most diverse and most abundant group of dragonflies. They can be found in a variety of size, shape and in non-iridescent colouration. Inner margins of eyes are meeting widely. Size, shape, colouration and transparency of wings vary greatly between species. Most of them are globally distributed and generalist species. They breed in a wide range of aquatic habitats including estuaries and polluted waters.

In Kerala this family was represented by 52 species of 31 genera (Nair et al. 2021). 33 species of 24 genera have been recorded as the representatives of this family by the current study.

21. **Genus *Acisoma*** Rambur, 1842

Small sized dragonfly having body colour blue with black markings. Head is small. Eyes join at a point. Narrow and small thorax. Wings are short with open reticulation and large pterostigma. Abdominal segments 1-5 are widely dilated and tapering from segments 6 to 10.

22. **Genus *Aethriamanta*** Kirby, 1889

One of the small sized dragonflies. Head is large in size. Eyes are meeting broadly at their inner margins. Thorax is smaller in size with long and robust legs. Transparent wings are coloured at the base. Abdomen is very short and fusiform.

23. **Genus *Brachydiplax*** Brauer, 1868

Dragonflies with medium sized body and small head. Eyes are broadly contiguous at their inner margin. Robustly built thorax with slender long legs and transparent wings. Abdominal segments are broader at the base and gradually tapering to apical end.

24. **Genus *Brachythemis*** Brauer, 1868

Small or medium sized dragonflies. Medium sized head with broadly contiguous eyes. Body colour is yellow with brown markings. Thorax and legs are robustly built. Transparent wings having yellowish or orange patches. Short and stout abdomen with segments tapering to the apical end.

25. **Genus *Bradinopyga*** Kirby, 1893

Dragonflies with medium body size. Ground colour is black with white or grey markings. Eyes are meeting broadly at their inner margins. Robust thorax with short slender legs and transparent wings. Abomen is slender with slightly dilated base.

26. **Genus *Crocothemis*** Brauer, 1868

Dragonflies with medium sized body and uniform red colour. Medium sized head. Eyes are contiguous to a short area. Thorax is robustly built with short robust legs and transparent wings. Abdomen is broad and the last segments are tapering to the end.

27. **Genus *Diplacodes*** Kirby, 1889

Small sized dragonflies. Greenish yellow ground colour with black markings or black coloured body with pruinescence. Eyes are contiguous in a short area. Narrow thorax with slender legs. Transparent wings are with or without black patches. Abdomen is slender but the basal segments are dilated.

28. **Genus *Hydrobasileus*** Kirby, 1889

Large sized dragonflies with ground colour ochreous of ferruginous. Large head with broadly contiguous eyes. Thorax is robust and the legs are long and slender. Transparent wings with coloured patches. Basal abdominal segments are broader and narrows gradually towards the base.

29. **Genus *Lathrecista*** Kirby, 1889

Dragonflies with moderately larger size. Medium sized head and broadly contiguous eyes. Thorax is robust and bronze coloured with yellow markings. Legs having moderate length and the wings are transparent. Abdomen is slender and reddish.

30. **Genus *Neurothemis*** Brauer, 1867

Medium sized dragonflies with medium sized head and shortly contiguous eyes. Robust thorax with slender legs. Broad wings are entirely or partially coloured. Abdomen is short with broad base and gradually tapers to the end.

31. **Genus *Onychothemis*** Brauer, 1868

Dragonflies with large sized dark metallic coloured body and yellow markings. Head is small sized and eyes are confluent at a short area. Robust thorax with long legs. Wings are transparent. Abdomen is broad and robust with tapering end and a high mid dorsal carina.

32. **Genus *Orthetrum*** Newman, 1893

Dragonflies with moderately large sized body. Eyes are confluent in a shorter or wider area. Robust thorax with short and robust legs. Wings are transparent. Abdomen is long and shape varies between species.

33. **Genus *Palpopleura*** Rambur, 1842

One of the genera of smallest sized damselflies. Large head with moderately confluent eyes. Robust thorax with slender moderately elongated legs. Wings are short and transparent with coloured patches. Abdomen is short and fusiform and pruinosed blue in matured adults.

34. **Genus *Pantala*** Hagen, 1861

Dragonflies with large body size. Gound colour of body is ochreous or reddish orange. Large head with broadly contiguous eyes. Robust thorax with slender legs. Broad elongated wings are transparent. Abdomen is dialated at base and have a constriction at segment 3 and tapering to the apical end.

35. **Genus *Potamarcha*** Karsch, 1890

Medium sized dragonflies having blackish brown body colour with yellow markings. Eyes meeting widely along inner margins. Robust thorax with slender legs. Slender abdomen is slightly wider at the base.

36. **Genus *Rhodothemis*** Ris, 1909

Large sized dragonflies with red body colour. Small sized head and eyes contiguous at a point. Robust thorax. Legs are long and robust. Wings are transparent with a basal coloured patch. Basal part of abdomen is slightly dilated and tapers to apical end.

37. **Genus *Rhyothemis*** Hagen, 1867

Dragonflies having medium body size, metallic body colour and entirely or partially coloured opaque wings. Small head with widely confluent eyes. Small thorax with long slender legs. Abdomen is short.

38. **Genus *Tetrathemis*** Brauer, 1868

Dragonflies having small body size and the abdomen is shorter than wings. Black body colour with citron yellow markings. Medium sized head with widely confluent eyes. Small and slender thorax and the legs are elongated and slim. Wings are transparent. Abdomen is short.

39. **Genus *Tholymis*** Hagen, 1867

Large sized dragonflies with robustly build body. Body colour is ochreous or reddish. Large head having widely confluent eyes. Robust thorax with long slender legs. Transparent wings with coloured patches. Abdomen has a broader base and tapering end.

40. **Genus *Tramea*** Hagen, 1867

Large sized dragonflies. Head is large and eyes are contiguous in a moderate area. Robust thorax with long slender legs. Wings are transparent and coloured and opaque at the base. Abdomen is slender with a slightly broader base.

41. **Genus *Trithemis*** Brauer, 1868

Dragonflies with medium sized body. Colour and shape vary between species. Medium sized head and the eyes are confluent moderately. Thorax is slim. Characteristics of legs also vary between species. Transparent wings with coloured base. Size and shape of abdomen also vary between species.

42. **Genus *Urothemis*** Brauer, 1868

Dragonflies with moderately large sized body. Large head with widely confluent eyes. Robust thorax with slender long legs. Transparent wings with partially coloured base. Abdomen with slightly dilated base and tapering apical end.

43. **Genus *Zygonyx*** Hagen, 1867

Dragonflies with large body size. Body colour is dark metallic with yellow markings. Head is large. Eyes are widely contiguous. Robust thorax with robust and

elongated legs. Wings are transparent. Abdomen is long and narrow and shorter than wings.

44. **Genus *Zyxomma*** Rambur, 1842

Slender crepuscular dragonflies having medium size. Large globular head and broadly confluent eyes. Thorax is small with long slender legs. Wings are transparent. Abdomen is well dilated at segments 1-3 and abruptly tapers to form very narrow till the end.

Detailed description of species recorded

Suborder Zygoptera

1. *Lestes elatus* Hagen in Selys, 1862

Size: Male: Abdomen- 34-36mm Hind wing- 23-24mm

Female: Abdomen- 34mm Hind wing- 24mm

Description: Male: Labium is white in colour. Labrum, cheeks, anteclypeus and eyes are turquoise blue. Bronze coloured triangular spot bordered with black is present at the inner side of each eye above. Thorax is dark reddish brown and pruinosed on sides. A pair of J shaped metallic green stripes expanding outwardly is present on dorsal side. This is a crucial distinguishing feature of this species. Legs are pale greenish yellow having a black stripe on femoral outer surface. Wings are transparent with black pterostigma. Abdomen pale bluish green having metallic green or bronze markings dorsally. Anal appendages are completely black in colour (Fraser, 1936).

Female: Almost similar to male with prominent markings but the ground colour is pale brown.

Behaviour and habitat: It is commonly found near ponds, streams and paddy fields. Weak flies and rests by keeping wings open and occasionally moving abdomen up and down. Usually lays eggs on wet grass surfaces (Kiran and Raju, 2013).

2. *Lestes praemorsus* Hagen in Selys, 1862

Size: Male: Abdomen: 32-35mm Hind wing: 21-22mm

Female: Abdomen: 30-32mm Hind wing: 20-21mm

Description: Male: Yellow coloured labium. Labrum, anteclypeus and cheeks are turquoise blue. Eyes are sapphire blue in colour. Thorax is black dorsally with a pair of dark green metallic antehumeral stripes having scalloped outer borders. Thorax is blue or greenish yellow laterally having irregular spots. In pruinosed forms these spots and antehumeral stripes are completely covered by pruinescence. Wings are transparent with dark reddish brown or blackish brown pterostigma. Legs are black in colour. Pale blue coloured abdomen is marked dorsally with bronzed green or coppery metallic. Segment 9 is marked with a lateral blue spot and segment 10 with a small ventro lateral spot.

Female: Similar to male but shows some differences. Labrum and cheeks are olivaceous. Thorax is yellowish or pale greenish blue laterally. Legs are ochreous instead of black.

Behaviour and habitat: It can be found commonly near ponds and marshes. Rests by keeping wings open and shows upward and down ward movement of abdomen similar to that seen in *Lestes elatus*. Robust fliers than other *Lestes* damselflies. Emergent grass surfaces are usually selected for egg laying.

3. *Protosticta gravelyi* (Laidlaw, 1915)

Size: Male: Abdomen: 46-49mm Hind wing: 20-22mm

Female: Abdomen: 33-35mm Hind wing: 19-23mm

Description: Male: Brownish black coloured labium. Labrum and clypeus are turquoise blue in colour. Frons, vertex and occiput are glossy black coloured. Eyes are dark bottle green above and light green below. A black triangle shaped marking is present at the middle of creamy white prothorax. Metallic black thorax with two creamy white lateral stripes on each side. Creamy white legs with darker knees. Transparent wings with black pterostigma. Abdomen is black coloured with white and turquoise blue markings. Half of the basal segment is turquoise blue. On dorsal side the apical black extends as a triangle into the basal blue. Segments 9 and 10 are without any markings.

Female: Females are almost similar to male in appearance but abdomen is shorter and stout. Segment 8 is black with basal large white spot on each side.

PLATE 3 – ODONATES OBSERVED DURING THE STUDY

Figure 3A*: Lestes elatus*

Figure 3B: *Neurobasis chinensis*

Figure 3C:*Vestalis apicalis*

Figure 3D: *Heliocypha bisignata*

Figure 3E: *Libellago indica*

Figure 3F*: Dysphaea ethela*

Behaviour and habitat: They are found among rocks and ferns of forested streams with dark shade cover. They are weak fliers. Usually found as small groups and lay eggs in forest streams.

4. *Neurobasis chinensis* (Linnaeus, 1758)

Size: Male: Abdomen: 45-50mm Hind wing: 32-38mm

Female: Abdomen: 44-50mm Hind wing: 36-40mm

Description: Male: Labrum turquoise blue in colour having a large black triangle marking. Eyes are blackish brown with white bottom. Thorax is bright metallic green with blackish brown humeral and antero-lateral stripes. Legs are elongated and black. Wings are without pterostigma. Fore wings are transparent with yellowish green tint. Hind wings are shorter than forewings. Hind wings are opaque and bright metallic green or peacock blue coloured and at the apex blackish brown in colour. Abdomen is considerably longer than wings and metallic green coloured.

Female: The major difference from male is the absence of coloured opaque wings. Wings are transparent tinted with pale brown. A creamy white spot is present at the nodes of all wings. Creamy white pterostigma is also present only in hind wings.

Behaviour and habitat: Commonly found in streams and rivers of forested habitats. Males show courtship behaviour through displaying the bright colouration of wings. Submerged decaying woods are used for depositing eggs (Subramanian, 2009).

5. *Vestalis apicalis* Selys, 1873

Size: Male: Abdomen: 49-55mm Hind wing:36-39mm

Female: Abdomen: 46-50mm Hind wing: 38-40mm

Description: Male: Head is metallic emerald green except labium, labrum, cheeks, bases of mandibles and bases of antennae which are yellow coloured. Eyes are brown above and pale yellow below. Thorax is metallic emerald green with black mid dorsal carina and fine pale yellow stripes. Legs are dark brown in colour. Wings are transparent. Distal portion of all wings about 5mm is tipped with

blackish brown. Pterostigma absent. Abdomen metallic emerald green having pale yellow markings and black intersegmental nodes.

Female: Females are similar to male with paler shades. Colour on wing tip is also paler. Coppery tint is prominent on abdomen and less metallic.

Behaviour and habitat: Commonly found in forested streams and rivers. Emergent plant parts or wet rocks are selected for egg deposition (Kiran and Raju, 2013)

6. *Vestalis gracilis* (Rambur, 1842)

Size: Male: Abdomen: 45-56mm Hind wing: 34-38mm

Female: Abdomen: 43-50mm Hind wing: 36-39mm

Description: Male: Labium, labrum, bases of mandibles, anteclypeus, cheeks and antennal bases are yellow in colour. The remaining portions of head are metallic green. Eyes are brown above and greenish yellow below. Thorax is metallic emerald green with fine black mid dorsal carina and fine yellow stripes. Legs are brown coloured with yellow tibial flexor surface and femoral extensor surface. Transparent wings tinted with greenish yellow and having iridescent blue shades. Abdomen metallic green above and black below.

Female: Closely similar in appearance with male. Metallic colours are dull.

Behaviour and habitat: Commonly found in forest areas but rarely seen in non-forest areas also. They are found as groups along with *Vestalis apicalis*. Submerged plant parts and logs are used as substratum for oviposition.

7. *Heliocypha bisignata* (Hagen in Selys, 1853)

Size: Male: Abdomen: 20mm Hind wing: 24-26mm

Female: Abdomen: 16mm Hind wing: 22mm

Description: Male: Head is black with dark brown eyes. Prothorax is black with a prominent large pink spot. Thorax is black with a rose pink coloured mesothoracic triangle and two larger spots of same colour on both sides of the former spot. Thorax also has yellow markings laterally. Black legs having white shades. Wings are transparent in basal part and tinted with yellow. Forewings have bright coppery colour at apical fourth part. Apical region of hind wing is opaque

and blackish brown coloured and glow with coppery or violaceous reflex from the vitreous spots of this region. Pterostigma is black. Black abdomen with yellow markings.

Female: The rose pink coloured markings on thorax is absent in females. The thorax is black and have yellow markings. Wings are transparent. Pterostigma is black with a central creamy patch.

Behaviour and habitat: Very common in forest habitats. Rarely found in some non-forested areas. Lays eggs on floating and decaying logs and submerged vegetation.

8. *Libellago indica* (Fraser, 1928)

Size: Male: Abdomen: 14-16mm Hind wing: 15-18mm

Female: Abdomen: 13-17mm Hind wing: 17-20mm

Description: Male: Head is black with ochreous labium and brownish yellow labrum. Eyes are brown above and pale grey below. Eyes have a bluish metallic luster. Thorax is black with yellow markings. Legs are black with pruinosed white shades. Transparent wings with amber tinted bases. Apices of forewings have black patch. Abdomen is black and yellow coloured. Last segments are almost black in colour.

Female: Females are dull coloured and stout bodied. Wings are transparent and amber tinted. Pterostigma creamy white bordered with black. Abdomen yellow with black markings.

Behaviour and habitat: Commonly seen in forested habitats and also found in non-forested regions. Territorial fights can be observed between males. Floating logs and submerged vegetation are selected for oviposition.

9. *Dysphaea ethela* (Fraser, 1924)

Size- Male: Abdomen:38mm Hind wing: 33mm

Female: Abdomen : 32mm Hind wing: 33mm

Description: Male: Head is velvety black. Eyes are black above and grayish below. Velvet black thorax having fine reddish yellow stripes. These are obscured in completely matured adults. Legs are black. Transparent wings are tinted with

brown. Pterostigma is black and elongated covering 7-8 cells. Abdomen is black and have brownish yellow apical annules and lateral stripes.

Female: Eyes are olivaceous brown above and bluish grey below. Black thorax has prominent and broad yellow markings. Yellow markings on abdomen are also extensive. A large triangle shaped yellow spot is present on both sides of 9^{th} segment.

Behaviour and habitat: Found in fast flowing rivers and streams of forested habitats. Usually perch on rocks or twigs in streams.

10. *Copera marginipes* (Rambur, 1842)

Size- Male: Abdomen: 28-31mm Hind wing: 16-18mm

Female: Abdomen: 29-30mm Hind wing: 20mm

Description- Male: Pale brown labium. Labrum, bases of mandibles, genae, ante and post clypeus are pale greenish yellow. Eyes are black above and pale greenish yellow below with a fine black equatorial band. Bronzed black thorax with bluish yellow stripes and markings. Markings on lateral sides are yellowish. Legs are yellowish orange. Transparent wings with yellow framed brown pterostigma. Abdomen is bronzed black upto 8^{th} segment. Segment 9 is bluish white or white on dorsum and black ventrally. Segment 10 is white or bluish white. Teneral individuals have white abdomen with fine black markings. Anal appendages are white and the inferiors have black tips. The length of superiors is half the length of 10^{th} segment. Inferiors are four times longer than superiors.

Female: Females are dull coloured. Markings of thorax are pale brown in colour. They have stout and cylindrical abdomen. Pale brown pterostigma.

Behaviour and habitat: Common in ponds, canals, streams, rivers and ditches of forests and non-forests. Always fly in closer distances to ground. Breed in marshes and streams.

11. *Copera vittata* (Selys, 1863)

Size- Male: Abdomen: 28-34mm Hind wing: 16-18mm

Female: Abdomen: 28-30mm Hind wing: 18mm

PLATE 4 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 4A*: Copera marginipes*

Figure 4B*: Copera vittata*

Figure 4C*: Onychargia atrocyana*

Figure 4D*: Prodasineura verticalis*

Figure 4E*: Aciagrion approximans krishna*

Figure 4F*: Aciagrion occidentale*

Description- Male: Labium reddish brown and labrum greenish yellow in colour. Eyes are brown above and olivaceous below with a fine black equatorial line. Thorax is bronzed black dorsally and have bluish white and pale brown markings. Markings on lateral sides are more yellowish. Legs are reddish yellow coloured. Wings are transparent with black long pterostigma. Abdomen is black dorsally and laterally upto segment 9 and segment 10 is entirely bluish white. Segment 9 has a bluish white patch on dorsal side. Anal appendages are pale blue or white. The length of superiors is equal to that of segment 10. Inferiors are twice longer than superiors.

Female: Females are dull coloured and more brownish in appearance. They have stout and cylindrical abdomen.

Behaviour and habitat: Commonly found in ponds, streams, puddles, canals and rivers. Fly in closer distances to the ground.

12. *Onychargia atrocyana* (Selys, 1865)

Size- Male: Abdomen: 23mm Hind wing: 17mm

Female: Abdomen: 23mm Hind wing: 18mm

Description: Male: Head is entirely black in fully matured adults. Eyes are black above and pale blue below. Thorax is velvety bluish black coloured. Fine citron yellow stripes can be seen in tenerals and subadults. These are obscured by pruinescence in fully matured individuals. Legs are black. Transparent wings with olivaceous yellow pterostigma. Abdomen black with pale blue basal rings.

Female: Females are similar in appearance of subadult males. Velvet black thorax with citron yellow stripes. Abdomen is black dorsally with yellow basal rings.

Behaviour and habitat: Rarely found in marshes, ponds and streams of forested and non-forested habitats. They have the ability to fly high and migrate to longer distances (Kiran and Raju, 2013)

13. *Prodasineura verticalis* (Selys, 1860)

Size- Male: Abdomen: 29mm Hind wing: 19mm

Female: Abdomen: 30mm Hind wing: 20mm

Description- Male: Velvety black head with pale brown labium. Labrum, bases of mandibles and genae are in reddish brown colour. Eyes are black above and brown below. Velvety black thorax having blood red and yellow stripes. Legs are black with reddish and ochreous shades. Transparent wings with dark reddish brown pterostigma. Abdomen black and have paired baso-dorsal spots are present in segments 3-7.

Female: Eyes are dark brown above and pale yellow below. Females have similar thoracic markings of males but markings are yellowish in colour.

Behaviour and habitat: Commonly found in streams, ponds and rivers. Perch on overhanging vegetation closer to water surface. Eggs are laid in running water or on plant parts closer to water (Kiran and Raju, 2013).

14. *Aciagrion approximans krishna* (Fraser, 1921)

Size- Male: Abdomen: 24-25mm Hind wing: 15mm

Female: Abdomen: 24-25mm Hind wing: 15-16mm

Description: Male: A black transverse band is present on pale labium and labrum. Black head with bright blue postocular spots connected by a blue stripe. Eyes are dark brown above and pale green below. Thorax is broadly black on dorsum with violaceous blue antehumeral stripes. Lateral sides are also violet blue. Legs have blue and black shades. Transparent wings with dark violet or black pterostigma. Violet blue abdomen is blackish on dorsum upto the 7^{th} segment. Segment 8 and 9 are violaceous blue in colour. Segment 8 is marked with lateral black stripe on each side. Segment 10 is black dorsally.

Female: Thoracic antehumeral stripes are pale bluish green in colour. Pterostigma dirty brown coloured.

Behaviour and habitat: Found in ponds, marshes and canals with slow moving water of high altitude regions. Floating or aquatic vegetation in stagnant water habitats are selected for oviposition (Joshi *et al.* 2016).

15. *Aciagrion occidentale* (Laidlaw 1919)

Size- Male: Abdomen: 23-24mm Hind wing: 15-16mm

Female: Abdomen: 24mm Hind wing: 16mm

Description: Male: Bluish white labium and labrum. Elongated blue postocular spots are connected by a fine blue line. Eyes are black above and pale blue below. Thorax is black dorsally and pale azure blue laterally. Fine greenish yellow ante humeral stripes are present. Pale blue legs with black shades. Transparent wings with blackish grey pterostigma. Slender abdomen is dorsally black upto the 7th segment. 8th and 9th segments are blue. Segment 8 has a narrow triangle shaped black marking on dorsum. Segment 10 is blue with x shaped black marking dorsally.

Female: Markings on thorax and abdomen are exactly similar to males except in segments 8-10. Segment 8 has a broad black marking dorsally. Segment 9 has a black patch on dorsal side at the basal end. Segment 10 is wholly blue. The antehumeral stripes are pale yellow.

Behaviour and habitat: Seen in marshes, canals and ponds of forests and non-forests. They have the ability to migrate. Breed in stagnant fresh water.

16. *Agriocnemis keralensis* (Peters, 1981)

Size- Male: Abdomen: 13mm Hind wing: 8mm

Female: Abdomen: 14mm Hind wing: 9mm

Description: Male: Labium, labrum, anteclypeus, postclypeus and bases of mandibles are pale yellowish green in colour. Two yellowish green postocular spots are present at the back of head. Green eyes are capped with black. Thorax is black on dorsum with apple green antehumeral stripes. Thorax is green on lateral sides. Legs are creamy white with black spines. Transparent wings with ochreous pterostigma. Abdomen is greenish in segments 1 and 2 changes to orange from 3 to 10 and all segments are marked with black. 2nd segment has a peculiar marking in the shape of cobra's hood.

Female: Head, prothorax and thorax are exactly similar with male. Abdomen is greenish yellow in colour with dorsal broad black stripe. Heteromorphic females can be seen with orange and pale brown ground colour.

Behaviour and habitat: Commonly seen in aquatic grasses of marshes and paddy fields, particularly in plains. (Koli *et al*., 2021)

17. *Agriocnemis pieris* (Laidlaw, 1919)

Size- Male: Abdomen: 16- 18mm Hind wing: 9-10mm

Female: Abdomen: 18mm Hind wing: 11mm

Description: Male: Labium is white in colour and labrum, bases of mandibles, genae and clypeus are pale azure blue. Eyes are black above and pale blue below. Black occiput has coma shaped white postocular spots and a fine median band between them. Thorax is black dorsally and pale blue laterally. Fine pale blue coloured antehumeral stripes are present. White legs with black markings. Transparent wings and the pterostigma is pale greyish white. Pale blue coloured abdomen having black markings upto the segment 7. Segment 8 is unmarked or having thin black basal annule. Segment 9 and 10 are unmarked.

Female: Females are similar to male but more bluish and have more extensive black markings on abdomen. Broad black markings are present on 1-9 segments. Segment 8 and 9 are black in most of the dorsolateral surfaces. Segment 8 has a lateral blue stripe extending from the basal end on each side. Segement 10 has a black marking on basal end. Immature females have orange ground colour.

Behaviour and habitat: Commonly found in forested and non-forested habitats. Fly among grasses and closer to the ground. Marshes, rivers and ponds are the breeding habitats.

18. *Agriocnemis pygmaea* (Rambur, 1842)

Size- Male: Abdomen: 16-17mm Hind wing: 9-10mm

Female: Abdomen: 18mm Hind wing: 11-12mm

Description: Male: Pale yellow coloured labium and bright metallic blue labrum. Black occiput with pale greenish round shaped postocular spots. Pale green eyes are capped with black. Apple green thorax marked dorsally with black and have apple green antehumeral stripes. Legs are yellow with black markings. Transparent wings. In forewings, pterostigma is yellow coloured and in hind wings it is black coloured. Abdomen is pale grrenish yellow upto 7^{th} segment and orange in segments 8-10 and anal appendages. Abdomen is broadly marked with black on dorsum upto 8^{th} segment. Pruinosed males are also found.

PLATE 5 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 5A*: Agriocnemis pieris*

Figure 5B*: Agriocnemis pygmaea*

Figure 5C*: Agriocnemis splendidissima*

Figure 5D*: Archibasis oscillans*

Figure 5E*: Ceriagrion cerinorubellum*

Figure 5F*: Ceriagrion coromandelianum*

Female: Different colour morphs are found in females. In red morphs, head, thorax and abdomen are dark brick red coloured. Thorax is marked with a dorsal broad black stripe. Terminal abdominal segments are suffused with black.

In androchrome forms, thorax is apple green and have dorsal balck stripe and bluish brown antehumeral stripes. Abdomen is almost similar with that of males.

Behaviour and habitat: They are common in all kinds of habitats like forests, plains and so on. Fly among grasses and closer to the ground. Breeds in ponds, marshes and rivers.

19. *Agriocnemis splendidissima* (Laidlaw 1919)

Size- Male: Abdomen: 18mm Hind wing: 10mm

Female: Abdomen: 17-18mm Hind wing: 12-13mm

Description: Male: Labium yellow coloured. Labrum, bases of mandibles, genae and ante clypeus are bluish. Comma shaped blue coloured postocular spots are present in black occiput. Geen eyes are capped with black. Thorax is black on dorsum and blue on sides. Black dorsal portion of thorax is marked with pinkish or pale bluish narrow stripes. Legs are black with bluish pruinescence. Transparent wings with black pterostigma. Abdomen is blue coloured with black markings. Superior anal appendages are peculiar with their narrow and curved hook like apperence.

Female: Females are similar to male but the ground colour is brownish or greenish yellow and stout abdomen.

Behaviour and habitat: They are not so common. Their distribution is more in higher altitudes than in plains. Ordinarily found among aquatic grasses of rivers, ponds and canals.

20. *Archibasis oscillans* (Selys, 1877)

Size- Male: Abdomen: 30-32mm Hind wing: 21-23mm

Female: Abdomen: 35mm Hind wing: 28mm

Discription: Male: Labium white and labrum turquoise blue. Eyes are dark blue above and pale blue below. Large triangular azure blue postocular spots are present. Thorax is black on dorsum with azure blue stripes. Lateral sides are also

azure blue in colour. Legs are creamy white with black markings. Wings are transparent and pterostigma is black, subquadrate shaped and framed in pale brown. Abdomen is black dorsally and laterally upto 7th segment. Segments 8-10 are azure blue and have apical black markings.

Female: Females have stouter abdomen and paler colours. 8th segment has a large dorsal black spot. 9th segment has two small black spots on dorsum. 10th segment is entirely azure blue.

Behaviour and habitat: Rarely found in streams and canals, particularly in forests or in habitats near to forests. Lay eggs on submerged vegetation.

21. *Ceriagrion cerinorubellum* (Brauer, 1865)

Size- Male: Abdomen: 31-33mm Hind wing: 20-21mm

Female: Abdomen: 31-35mm Hind wing: 20-21mm

Description: Male: White coloured labium and dark olivaceous labrum. Eyes are pale bluish above and greenish below. Thorax is greenish on dorsum, bluish on sides and yellowish beneath. Yellowish legs with black spines. Transparent wings and pterostigma amber coloured. Abdomen is orange coloured in segments 1, 2 and basal half of 3, apical half 7 and segments 8-10 are reddish orange. The central segments are black dorsally.

Female: Females are with paler colours and stouter abdomen.

Behaviour and habitat: Very common in ponds, canals, marshes, paddy fields and rivers of forested and non-forested habitats. Found among grasses.

22. *Ceriagrion coromandelianum* (Fabricius, 1798)

Size- Male: Abdomen: 28-30mm Hind wing: 18-20mm

Female: Abdomen: 29-32mm Hind wing: 20mm

Description: Male: Labium, labrum, clypeus, genae, bases of mandibles and frons are citron yellow coloured. Olive green eyes changes to greenish yellow below. Thorax is olive green on dorsum pale greenish yellow on sides. Legs are citron yellow with black spines. Wings are transparent and the pterostigma is golden yellow in colour. Abdominal segments are evenly citron yellow coloured.

PLATE 6 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 6A*: Ceriagrion rubiae*

Figure 6B*: Paracercion calamorum*

Figure 6C: *Paracercion malayanum*

Figure 6D: *Pseudagrion malabaricum*

Figure 6E*: Pseudagrion rubriceps*

Figure 6F*: Pseudagrion indicum*

Female: Females are large and stout bodied and with dull colours. Thorax is olivaceous brown and abdomen is golden yellow or brownish yellow.

Behaviour and habitat: Very common in distribution. Found in ponds, canals, ditches, rivers and lakes and backwaters. Breed in marshes and stagnant ponds with aquatic grass and vegetation.

23. *Ceriagrion rubiae* (Laidlaw, 1916)

Size- Male: Abdomen: 26-29mm Hind wing: 17-18mm

Female: Abdomen: 30-31mm Hind wing: 20mm

Description: Male: Pale yellow coloured labium. Labrum, clupeus and frons are ochreous coloured. Eyes are dark olivaceous above and paler below. Thorax is bright orange on dorsum and yellowish on sides. Legs are brownish yellow and having black spines. Wings are transparent with amber coloured perostigma. Abdomen is bright orange in colour.

Female: Females are robust bodied and dull coloured. The orange tint of thorax and abdomen is replaced by olivaceous.

Behaviour and habitat: Rarely found in forested habitats or in regions not far from forests. Breed in marshes and ponds with grasses and aquatic vegetation.

24. *Ischnura rubilio* (Selys, 1876)

Size- Male: Abdomen: 16-20mm Hind wing: 10-12mm

Female: Abdomen: 18-20mm Hind wing: 14-15mm

Description: Male: White coloured labium and citron yellow coloured labrum. Small round, azure blue coloured postocular spots are present. Eyes are olive green, darker above and paler beneath with a small cap of black. Thorax is broadly bronzed black on dorsum with grass green stripes. Lateral sides are grass green in colour. Pale yellow legs are marked with black. Transparent wings. Pterostigma vary in size and shape in fore and hind wings. In fore wings it is kite shaped and rose red in proximal half and transparent in remaining portion. In hind wing it is smaller and pale greyish in colour. Abdomen is bright yellow upto the segment 7 and the remaining segments are azure blue in colour. A dorsal diamond shaped spot

is present near the apical end of segement 6. Segment 7 is bronzed black dorsally. Segment 10 has a dorsal broad black spot.

Female: Thorax is pale green laterally. The azure blue colour of last segments is absent in females. Abdomen is pale yellow or pale brownish and a dorsal broad black stripe is present on all abdominal segments.

Behaviour and habitat: Commonly found in forested, non-forested habitats and also in brackish water habitats. Ordinarily seen in ponds, rivers, marshes, canals, lakes and back waters.

25. ***Ischnura senegalensis*** **(Rambur, 1842)**

Size- Male: Abdomen: 21-23mm Hind wing: 13-15mm

Female: Abdomen: 20-24mm Hind wing: 14-16mm

Description: Male: Pale yellow coloured labium and pale blue coloured labrum. Eyes are green coloured above, yellowish beneath and capped with black. Thorax is broadly black dorsally with citron yellow or pale green stripes and pale green on sides. Black legs are marked with yellow. Wings are transparent and pterostigma varies in fore and hind wings. In forewings it is black with white costal border and in hindwings it is pale brown framed with black. Abdomen is dorsally black in all segments except segment 8. Remaining portion of segments 1 and 2 are azure blue and pale green coloured. Segements 3-7 are yellow on sides. Segment 8 is azure blue. Segment 9 is azure blue on sides and segment 10 is yellow laterally.

Female: Females are found in different forms. Generally, they are dull coloured and blue colour on abdomen is completely absent. They are red or brown tinted. But in androchrome forms they look exactly like males.

Behaviour and habitat: Very common in high altitude forests, plains and brackish water habitats. Found in marshes, ponds, rivers, streams, lakes and wet grasslands. Stagnant ponds and marshes are the oviposition sites.

26. ***Paracercion calamorum*** **(Ris, 1916)**

Size- Male: Abdomen: 22-23mm Hind wing: 16mm

Female: Abdomen: 21-23mm Hind wing: 15-16mm

Description: Male: Head, thorax and legs are pruinosed in matured adults. Vertex and occiput are black. Postocular spots are blue coloured. In old adults these are obscured by pruinescence. Eyes are brown above and yellowish green below. Thorax is black on dorsum and blue on sides, entirely hidden by bluish white pruinescence in old adults. Pale bluish legs with black markings obscured by pruinescence. Transparent wings with pale yellow pterostigma framed in black. Abdomen azure blue broadly marked with black on segments 1-7. Segments 8-10 are azure blue. Segments 8 and 9 are marked with fine black apical fringe. Segment 10 with a narrow black stripe along the mid dorsal carina.

Female: Females are with ground colour yellowish green. All abdominal segments are marked broadly with black on dorsum.

Behaviour and habitat: Rarely found in paddy fields and weedy ponds. Perch on floating leaves.

27. *Paracercion malayanum* (Selys, 1876)

Size- Male: Abdomen: 22mm Hind wing: 15mm

Female: Abdomen: 20mm Hind wing: 15mm

Description: Male: Black coloured vetex and occiput with bluish green postocular spots. Other parts of head is azure blue coloured. Eyes are deep blue coloured. Thorax is black on dorsum with broad azure blue stripes. Lateral sides are also blue in colour. Pruinescence on thorax is absent. Pale bluish legs with black markings and black spines. Transparent wings and pterostigma is pale yellow with black frame. Azure blue coloured abdomen is marked dorsally with broad black stripe upto segment 7. Segment 2 has a peculiar thistle head shaped black coloured marking on dorsum. Segments 8-10 are azure blue and segments 8 and 9 with narrow black apical fringe. There is a fine black stripe on the mid dorsal carina of segment 10.

Female: Females are with yellowish green ground colour. Greenish yellow thorax marked with black. Abdominal segments are broadly black on dorsum with pale green rings.

Behaviour and habitat: Rarely found in aquatic grasses and floating vegetation of ponds and paddy fields.

28. *Pseudagrion australasiae* Selys, 1876

Size- Male : Abdomen: 30-32.5mm Hind wing: 20-21mm

Female: Abdomen: 29mm Hind wing: 20mm

Description: Male: Pale yellow coloured labium. Labrum, bases of mandibles, clypeus, genae and frons are pale greenish blue. Postocular spots are large and bluish in colour. Eyes are blue coloured capped with black. Bright azure blue coloured thorax with broad black stripes on dorsum. Pale bluish legs with black markings. Wings are transparent and the pterostigma is dark brown in colour. Abdomen is azure blue in colour marked with black broadly on dorsum upto segment 7. Segments 8-10 are azure blue. Segments 8 and 9 are with fine black apical rings. There is a broad X shaped marking on segment 10 dorsally. Superior anal appendages are bifid at the apex and length is half that of segment 10.

Female: Thorax is pale greenish blue coloured with black stripes. Abdomen is pale blue with broad dorasal stripe of black upto segment 9.

Behaviour and habitat: Found in forests or habitats not far from forests. Breeds in weedy ponds and marshes.

29. *Pseudagrion decorum* (Rambur, 1842)

Size- Male: Abdomen: 28-30mm Hind wing: 18-20mm

Female: Abdomen: 31mm Hind wing: 20mm

Description: Male: Labium whitish. Labrum, genae, bases of mandibles, clypeus, frons and vertex are coloured pale bluish green. Postocular spots are deep azure blue and triangle shaped. Colour of eyes changes from blue, bluish green to pale green from top to bottom and also with a small cap of black. Thorax is bluish green dorsally and azure blue on sides. Thorax has three peculiar fine mid dorsal lines. Pale bluish legs are with black markings. Transparent wings. Pterostigma whitish brown and diamond shaped. Abdomen azure blue and marked dorsally with black except segments 8-10. Segments 8-10 are azure blue marked with black apical rings.

Female: Females with greenish yellow ground colour. Markings on thorax is similar with that of males. Dorsal black abdominal markings are present upto segment 9.

Behaviour and habitat: Rarely found in weedy ponds, lakes and marshes. Perch on emergent grasses. Exhibit migratory behaviour.

30. *Pseudagrion indicum* (Fraser, 1924)

Size: Male: Abdomen: 34mm Hind wing: 22mm

Female: Abdomen: 32mm Hind wing: 22mm

Description: Male: white coloured labium. Pale yellowish green labrum and cheeks. Eyes are green coloured and with black cap. Thorax is broadly black on dorsum with broad grass green stripes. Lateral sides are azure blue in colour. Pale blue legs with black stripes. Transparent wings with blackish brown pterostigma. Abdomen is azure blue coloured with a broad dorsal stripe of black upto segment 7. Segments 8 and 9 are entirely azure blue and having broad black apical rings.

Female: The blue colour on lateral sides of thorax is replaced with pale yellowish green. Ground colour of abdomen is blue with black stripe, similar to male. Segments 8 and 9 are broadly black on dorsum and segment 10 is blue with narrow black basal ring.

Behaviour and habitat: This species is endemic to the Western Ghats. These are found in streams, rivers and ponds of forested habitats and regions near to forests and hills.

31. *Pseudagrion malabaricum* (Fraser, 1924)

Size- Male: Abdomen: 33mm Hind wing: 20mm

Female: Abdomen: 32mm Hind wing: 22mm

Description: Male: Labium whitish and labrum is azure blue coloured. Turquoise blue eyes are capped with black. Azure blue coloured thorax is marked dorsally with three broad black stripes. Legs are pale blue with black markings. Transparent wings with dark brownish pterostigma. Abdomen is azure blue marked with black dorsally on segments 1-7. Segments 8-10 are azure blue. Segments 8 and 9 have narrow apical black coloured rings. Segment 10 has a dorsal broad black marking. Superior anal appendages are black and slightly shorter than segment 10. These are not bifid and curled inward.

Female: Thorax is pale greenish blue coloured. Stripes on thorax are similar to male. Pale blue coloured abdomen. The dorsal black stripe is present upto segment 9.

Behaviour and habitat: Not a common species. Found in forests or in regions near to forests. Breeds in weedy ponds and marshes.

32. *Pseudagrion microcephalum* (Rambur, 1842)

Size- Male: Abdomen: 27mm Hind wing: 17mm

Female: Abdomen: 29mm Hind wing: 20mm

Description: Male: Labium, labrum and genae are pale blue in colour. Postocular spots are very large and azure blue coloured. Eyes are pale blue beneath and azure blue above with a small brown cap. Azure blue coloured thorax with broad black stripes on dorsum. Pale blue legs with black stripes. Transparent wings. Pterostigma grey coloured and framed with black. Abdomen azure blue coloured and marked with black. Segments 1-7 are marked dorsally with broad black stripes. Segment 2 has a goblet shaped marking. Segment 8 has thick annule and segment 9 has a thin annule apically. Segment 10 is marked broadly on dorsum with black. Superior anal appendages are black with inner side blue and same length of segment 10 and bifid at the apex.

Female: Differs from male in colour and markings. Thorax with bluish green ground colour, dorsally suffused with orange and narrow black stripes. Pterostigma pale brown coloured. Pale blue coloured abdomen with black broad dorsal stripe upto segment 9. Segment 2 has a dumbbell shaped marking. Markings are absent on Segment 10.

Behaviour and habitat: This species is common in plains. Found in ponds, canals, marshes rivers and paddy fields. Breeds in marshy and vegetated aquatic habitats. Exhibits migratory behavior (Kiran and Raju, 2013).

33. *Pseudagrion rubriceps* (Selys, 1876)

Size- Male: Abdomen: 29mm Hind wing: 18-20mm

Female: Abdomen: 29mm Hind wing: 21mm

PLATE 7 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 7A*: Pseudagrion microcephalum*

Figure 7B*: Gynacantha dravida*

Figure 7C*: Ictinogomphus rapax*

Figure 7D*: Acisoma panorpoides*

Figure 7E*: Aethriamanta brevipennis*

Figure 7F*: Brachydiplax chalybea*

Description: Male: Bright orange colour of face is the peculiar character of this species. Eyes are orange above and golden yellow beneath. Large dark bluish triangle shaped postocular spots are present. Thorax is golden olivaceous green dorsally with black stripes. Lateral sides are azure blue coloured. Pale yellow coloured legs with black shades. Wings are transparent and the perostigma is diamond shaped and reddish brown coloured. Abdomen is azure blue with broad dorsal black stripe on segments 1-7. Segment 8 has a triangle shaped apical dorsal marking. Markings are absent on segments 9 and 10.

Female: Bright orange colour is replaced with yellowish green on face, thorax and eyes. Lateral sides of thorax and abdomen is pale blue in colour. Black dorsal broad marking on abdomen is extended upto segment 9. Segment 10 is unmarked.

Behaviour and habitat: Commonly found in streams, rivers, ponds and streams of forested and non-forested habitats. Seen in groups of 3-4.

Suborder Anisoptera

34. *Anax guttatus* (Burmeister, 1839)

Size- Male: Abdomen: 56-62mm Hind wing: 50-54mm

Female: Abdomen: 56-58mm Hind wing: 52-54mm

Description: Male: Labium and labrum are ochreous coloured. Eyes are greenish or greenish blue in colour. Thorax is unmarked and pale green coloured. Legs are black coloured. Wings are transparent. Central portion of hind wings have large brownish yellow patch. Pterostigma is ferruginous coloured. Abdominal segments 1 and 2 are pale greenish, segment 2 is turquoise blue on dorsum and segment 3 has a pair of triangle shaped turquoise blue markings dorsally. 3 pairs of orange coloured spots are present on segments 4-7. Segments 8 and 9 have fewer spots and segment 10 is yellow with a basl reddish brown annule.

Female: Females show close similarity to males but colours are duller. The brownish yellow patch on hind wing is absent.

Behaviour and habitat: Common species of forested and non-forested habitats. Found in weedy ponds, lakes, marshes. It is diurnal species and attracted by light during night.

35. *Anax immaculifrons* (Rambur, 1842)

Size- Male: Abdomen: 52-55mm Hind wing: 55mm

Female: Abdomen: 56mm Hind wing: 58-60mm

Description: Male: Labium ochreous and labrum greenish yellow coloured. Eyes are sapphire blue in colour. Pale bluish green thorax with broad black lateral stripes. Legs are black. Transparent wings are tinted with brownish yellow. Colour of perostigma varies from ochreous to reddish brown. Abdomen with a ground colour of pale reddish brown and black markings.

Female: Closely similar to male. But instead of the turquoise blue colour, greenish yellow is the ground colour of thorax and base of abdomen.

Behaviour and habitat: Common species in forested and non-forested habitats. Found in rivers, canals and estuaries. Lays eggs by piercing submerged plant parts.

36. *Gynacantha dravida* (Lieftinck, 1960)

Size- Male: Abdomen: 50-58mm Hind wing: 43-50mm

Female: Abdomen: 48-55mm Hind wing: 44-50mm

Description: Male: Olivaceous brown face with peculiar T shaped marking on frons. Eyes are brownish blue. Brown coloured thorax. Legs are reddish brown. Transparent wings are tinted with reddish brown and having reddish brown pterostigma. Pale brown coloured abdomen with dark brown markings. Segment 3 is constricted. In fully matured adults bright bluish or greenish colours appear on thorax and first abdominal segments.

Female: Females are similar to males with duller colours.

Behaviour and habitat: This is a crepuscular species. Rests among dark vegetation during day time. Attracted by light during night. Found around weedy ponds, streams and marshes of forested and non-forested areas. Oviposit on soil adjacent to water bodies and the eggs reach in water during rain.

37. *Gynacantha millardi* Fraser, 1920

Size- Male: Abdomen: 46mm Hind wing: 44mm

Female: Abdomen: 45mm Hind wing: 43-45mm

Description: Male: Labium and labrum are pale yellowish. Eyes are greyish above and yellowish green below. Thorax is bright olive green or grass green. Yellowish brown legs. Wings are transparent with ochreous pterostigma having fine black frame. Abdomen is pale brown dorsally with dark brownish and black markings. Segments 1-3 are grass green laterally. Segment 3 is not constricted and this characteristic helps to distinguish from the similar species *Gynacantha bayadera*.

Female: Exactly similar to male. Colours are duller in females.

Behaviour and habitat: This is a crepuscular species. During day time they rest on vegetation. Rarely found around marshes and weedy ponds surrounded by thick vegetation.

38. *Ictinogomphus rapax* (Rambur, 1842)

Size- Male: Abdomen: 52mm Hind wing: 40mm

Female: Abdomen: 50mm Hind wing: 42-44mm

Description: Male: Labium and labrum are yellow with black frame. Bluish grey coloured eyes. Black coloured thorax with yellow markings. Legs are black in colour and marked with yellow. Transparent wings. Pterostigma black. Abdomen black with yellow markings.

Female: Females show close similarity with males with stouter abdomen and extensive yellow markings.

Behaviour and habitat: It is a commonly found species. Strong, agile flier. Both running and still water is used for breeding.

39. *Acisoma panorpoides* (Rambur, 1842)

Size- Male: Abdomen: 15-18mm Hind wing: 16-21mm

Female: Abdomen: 15-18mm Hind wing: 17-22mm

Description: Male: Labium and labrum pale yellowish. Pale blue coloured face. Eyes are bright blue coloured and have black spots. Azure blue coloured thorax is marbled with black. Legs are black with pale yellow stripes. Wings are transparent and the pterostigma is pale yellow in colour. Abdomen is also azure blue with black markings. Segments 1-5 are well dilated and the remaining

segments are slender. This is an identifying feature of this species. Segments 8-10 are entirely black and the anal appendages are white coloured.

Female: Shows similarity with males in shape and markings of thorax and abdomen. Eyes are greenish in colour and the ground colour of body is greenish yellow.

Behaviour and habitat: It is a common species of plains and weak flier. Found always closer to water among aquatic grasses and reeds. Breeds in marshes, vegetated ponds and paddy fields.

40. *Aethriamanta brevipennis* (Rambur, 1842)

Size- Male: Abdomen: 17-20mm Hind wing: 23-26mm

Female: Abdomen: 16mm Hind wing: 23mm

Description: Male: Small sized dragonfly. Eyes are dark reddish brown above and paler beneath. Thorax is dark chocolate brown in colour. Legs are black and having a bright red spot at the extensor surface of the distal ends of hind femora. Transparent wings with dark golden amber coloured tint at the base. Pterostigma is dark brown coloured. Abdomen is bright reddish. Anal appendages are red.

Female: In females the ground colour is yellow. Eyes are reddish brown above and greyish beneath. The red colour of femoral spot is replaced with citron yellow. Thorax and abdomen are golden olivaceous with black markings.

Behaviour and habitat: This species is commonly found in rivers, ditches, canals and weedy ponds. They exhibit obelisk posture in hot sunny days.

41. *Brachydiplax chalybea* (Brauer, 1868)

Size- Male: Abdomen: 21-25mm Hind wing: 26-30mm

Female: Abdomen: 21-23mm Hind wing: 27-29mm

Description: Male: Eyes are dark brown above and greyish beneath. Thorax is grey dorsally due to pruinescence and ochreous on sides. Legs are black with ferruginous shades. Wings are transparent and the bases are tinted with dark brown. Pterostigma is yellow coloured. Abdomen dorsally black with white pruinescence. Anal appendages are black.

Female: Thorax and abdomen are ochreous with black markings.

Behaviour and habitat: Common dragonfly found in estuaries, marshes, ponds, ditches, paddy fields and rivers.

42. *Brachydiplax sobrina* (Rambur, 1842)

Size- Male: Abdomen: 20-24mm Hind wing: 25-28mm

Female: Abdomen: 16-22mm Hind wing: 22-26mm

Description- Male: Eyes are reddish brown above and pale bluish beneath. Thorax is olivaceous brown in colour and dorsally pruinosed with bluish white. Black legs. Transparent wings having pale yellowish pterostigma. Abdomen is black in colour and segments 1-7 have bluish white pruinescence. Anal appendages are black.

Female: Thorax and abdomen are yellow in colour and marked with black.

Behaviour and habitat: It is not commonly seen. Generally found in paddy fields, marshes and ponds.

43. *Brachythemis contaminata* (Fabricius, 1793)

Size- Male: Abdomen: 18-21mm Hind wing: 20-23mm

Female: Abdomen: 18-20mm Hind wing: 22-25mm

Description: Male: Small dragonfly. Eyes are brown above and greyish beneath. Thorax is olivaceous brown with reddish brown stripes on sides. Legs are ochreous with brownish or blackish shades. Transparent wing with red venation and a bright orange patch extending from wing base to pterostigma. Pterostigma is rust red in colour. Abdomen is ochreous red with brown stripes. Anal appendages are rusty.

Female: Thorax is yellow coloured with black and brown markings.

Behaviour and habitat: This is a commonly found species especially in non-forested areas. Stagnant or slowly flowing water bodies including weedy ponds, paddy fields, marshes, canals, rivers and ditches are the breeding habitats. They can survive in habitats having polluted water. Presence of this species in pristine habitats indicates the increased disturbance of that habitat.

44. *Bradinopyga geminata* (Rambur, 1842)

Size- Male: Abdomen: 26-29mm Hind wing: 33-36mm

Female: Abdomen: 26-29mm Hind wing: 32-36mm

Description: Eyes are brownish above and greyish below. Thorax is ashy grey marbled with black. Legs are greyish with pruinescense. Transparent wings and the pterostigma is bicoloured, centrally black and whitish on both ends. Abdomen is black marbled with pale dirty yellow. Anal appendages are creamy white in colour.

Female: Females are closely similar to male. They can be differentiated through sexual characters.

Behaviour and habitat: Common species of forested and non-forested habitats. Small sized stagnant water bodies such as rock pools, overhead tanks, garden tanks, wells and ponds are the preferred habitats. They are used as mosquito control agent in some countries.

45. *Crocothemis servilia* (Drury, 1770)

Size- Male: Abdomen: 24-35mm Hind wing: 27-38mm

Female: Abdomen: 25-32mm Hind wing: 31-37mm

Description: Male: Eyes are blood red in colour and paler below. Thorax is blood red coloured. Legs are reddish ochreous. Transparent wings with amber yellow patch at the base. Pterostigma is dark ochreous. Blood red abdomen with a fine black mid dorsal carina. Anal appendages are blood red.

Female: Females vary widely in colouration from males. Eyes are brown above and pale yellowish green below. Thorax is olivaceous brown. Abdomen ochreous with black mid dorsal carina.

Behaviour and habitat: It is common particularly in non-forested habitats like paddy fields, weedy ponds, marshes, ditches and canals.

46. *Diplacodes nebulosa* (Fabricius, 1793)

Size- Male: Abdomen: 15-17mm Hind wing: 17-19mm

Female: Abdomen: 14-15mm Hind wing: 18mm

PLATE 8 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 8A*: Brachythemis contaminata*

Figure 8B*: Bradinopyga geminata*

Figure 8C: *Crocothemis servilia*

Figure 8D*: Diplacodes trivialis*

Figure 8E: *Hydrobasileus croceus*

Figure 8F: *Lathrecista asiatica*

Description: Male: Eyes are brownish above and greyish yellow beneath. Thorax, legs and abdomen are black. In old adult, body is slightly pruinosed. Transparent wings are tipped with blackish brown. Pterostigma is black.

Female: Thorax and abdomen of females are yellow with black markings.

Behaviour and habitat: This is not a commonly found species. Seen in weedy ponds and marshes. Flies in short heights.

47. *Diplacodes trivialis* (Rambur, 1842)

Size- Male: Abdomen: 19-22mm Hind wing: 22-23mm

Female: Abdomen: 18-20mm Hind wing: 22-24mm

Description: Male: Small sized dragonfly. Eyes are bluish brown above and pale blue beneath. Thorax is greenish yellow and dorsally it is violaceus brown with fine black markings. In old adults the thorax is covered with blue pruinescence. Legs are black marked with yellow. Wings are transparent. Pterostigma is dark greyish or black. Abdominal segments 1-7 are greenish yellow and marked with black. Segments 8-10 are entirely black and the anal appendages are yellow. In old adult, abdominal segments are also pruinosed with blue.

Female: Eyes are brownish above and yellow beneath. Abdomen and thorax are greenish yellow with black markings.

Behaviour and habitat: It is a common species of forested and non-forested habitats. Found around ponds, paddy fields, canals and streams. Always flies in short heights, closer to the ground and seen in gardens, play grounds, meadows and pathways.

48. *Hydrobasileus croceus* (Brauer, 1867)

Size- Male: Abdomen: 29-33mm Hind wing: 40-42mm

Female: Abdomen: 28-34mm Hind wing: 42-48mm

Description: Male: Large sized dragonfly. Eyes are reddish brown above and olivaceous beneath. Thorax is olivaceous brown in colour. Legs are ochreous. Transparent wings with pale brownish tint. The base of hind wing at the posterior end is marked with a broad reddish brown patch. Pterostigma is rusty brown anteriorly and ochreous posteriorly. Abdominal segements are ochreous at the

initial segments and reddish or ochreous at the last segments are have black markings. Anal appendages are reddish brown coloured.

Female: Females are stouter but similar to male in all respects.

Behaviour and habitats: This is not a common species. Found around weedy ponds, marshes and lakes. Genrally flies in heights.

49. *Lathrecista asiatica* (Fabricius, 1798)

Size- Male: Abdomen: 27-32mm Hind wing: 33-37mm

Female: Abdomen: 27-32mm Hind wing: 34-36mm

Description: Male: Eyes are reddish brown above and bluish grey below. Thorax is dark coppery brown dorsally and yellow laterally with brown stripes. Legs are dark reddish brown with yellow shade on anterior femora. Transparent wings are enfumed at tips and with reddish brown pterostigma. Abdomen is bright crimson red upto segment 8. Segments 9 and 10 and anal appendages are wholly black in colour.

Female: Females are almost similar to males. The colour of abdomen is olivaceous brown. Greenish yellow mid dorsal carina is present which is bordered with black.

Behaviour and habitat: It is common in forested and non forested habitats including ponds and marshes.

50. *Neurothemis fulvia* (Drury, 1773)

Size- Male: Abdomen: 21-26mm Hind wing: 27-32mm

Female: Abdomen: 20-24mm Hind wing: 26-32mm

Description: Male: Eyes are reddish brown above and brownish beneath. Prothorax and thorax are reddish brown in colour. Legs are rusty coloured. Wings are dark reddish brown except at tips. Pterostigma is reddish brown. Abdomen is reddish brown with ferruginous anal appendages.

Female: Head, thorax and abdomen of females are rusty brown coloured. Wings are amber yellow coloured.

PLATE 9 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 9A: *Neurothemis fulvia*

Figure 9B*: Neurothemis tullia*

Figure 9C: *Onychothemis testacea*

Figure 9D: *Orthetrum chrysis*

Figure 9E: *Orthetrum luzonicum*

Figure 9F: *Orthetrum pruinosum*

Behaviour and habitat: Found around ponds, rivers, streams and canals of forested and non forested habitats.

51. *Neurothemis tullia* (Drury, 1773)

Size- Male: Abdomen: 16-20mm Hind wing: 19-23mm

Female: Abdomen: 16-19mm Hind wing: 20-23mm

Description: Male: Eyes are dark brown above and olivaceous beneath. Thorax is black and having a pale yellowish mid dorsal carina. Legs are black. Basal half of wing is black which is bordered with milky white patch at the distal end and transparent at the tips. Pterostigma is dirty ochreous. Abdomen is black and having creamy white mid dorsal carina. Anal appendages are creamy white with black tips.

Female: Thorax is greenish yellow with a yellow mid dorsal stripe and two broad black stripes. Basal half of wing is tinted with amber yellow bordered with brownish black patch at the distal end followed by an area of pale yellow reticulation. The wing tips are opaque and brownish black. Abdomen is yellowish with two broad black stripes.

Behaviour and habitat: Common in a wide variety of habitats including paddy fields, ponds, canals, lakes, ditches, streams, rivers and marshes with short and weak flights.

52. *Onychothemis testacea* (Laidlaw, 1902)

Size- Male: Abdomen: 34-36mm Hind wing: 40-42mm

Female: Abdomen: 36mm Hind wing: 42-44mm

Description: Male: Eyes are bottle green in colour. Dark metallic bluish thorax with citron yellow mid dorsal carina and lateral stripes. Legs are black. Transparent wings with black pterostigma. Abdomen is black with citron yellow spots. Anal appendages are black and slim.

Female: Females are similar to males but with stouter abdomen.

Behaviour and habitat: It is not common. Found in streams and rivers of forested habitats.

53. *Orthetrum chrysis* (Selys, 1891)

Size- Male: Abdomen: 28-33mm Hind wing: 31-38mm

Female: Abdomen: 25-30mm Hind wing : 31-36mm

Description: Male: Brownish eyes and reddish face. Thorax is dark rusty brown. Legs are reddish black. Transparent wings and the wing base has an amber coloured patch and dark reddish brown pterostigma. Abdomen is bright blood red.

Female: Females are with brownish thorax and bright ochreous abdomen. The patch at the wing base is absent. There are expansions on segment 8 bordered broadly with black.

Behaviour and habitat: Common species of paddy fields, ponds, rivers, ditches, marshes,,lakes streams and canals. They can tolerate polluted water to some extent.

54. *Orthetrum glaucum* (Brauer, 1865)

Size- Male: Abdomen: 29-35mm Hind wing: 33-40mm

Female: Abdomen: 30mm Hind wing: 36mm

Description: Male: Face is olivaceous brown in younger and glossy black in older individuals. Eyes are dark green in colour. Thorax is dark dull blue with pruinescence. Legs are black. Transparent wings have dark amber coloured small patch at the base. Pterostigma is dark ochreous finely framed with black. Abdomen is pale blue with pruinescence at segments 1-8 and segments 9 and 10 are black. Anal appendages are black.

Female: Thorax is olivaceous in colour with dark reddish brown stripes. Abdomen is reddish brown and has yellowish stripes.

Behaviour and habitat: Common in forested habitats but rare in non forested areas. Found around marshes, streams and canals.

55. *Orthetrum luzonicum* (Brauer, 1868)

Size- Male: Abdomen: 28-30mm Hind wing: 30-32mm

Female: Abdomen: 28-32mm Hind wing: 30-32mm

Description: Male: Eyes are bluish green with brown spots. Face and frons are pale blue or pale greenish yellow in colour. Thorax is pale olivaceous green with lateral reddish brown stripes. Legs are blackish brown with bright yellow markings. Transparent wings with black bordered ochreous pterostigma. Abdomen is pale azure blue with pruinescence and very thin black markings. Anal appendages are blackish brown.

Female: Thorax of females are greenish yellow with brown mrkings. Abdomen is greenish yellow marked with black stripes.

Behaviour and habitat: Common species of forested and non forested habitats. Found around marshes, streams, ponds, ditches and paddy fields.

56. *Orthetrum pruinosum* (Burmeister, 1839)

Size- Male: Abdomen: 28-31mm Hind wing: 32-36mm

Female: Abdomen: 30mm Hind wing: 37mm

Description: Male: Face is ochreous or pale brownish. Eyes are bluish black above and bluish grey beneath. Thorax is brownish and with dull purple pruinescence. Legs are black. Transparent wings are having pale brownish tint at the apices and the pterostigma is reddish brown coloured. Abdomen is bright red which changes to purplish red when pruinosed. Anal appendages are red.

Female: Thorax is reddish brown or ochreous with brown stripes. Thorax is not pruinosed. Abdomen is ochreous with fine black markings on sutures and borders.

Behaviour and habitat: Commonly found in ponds, rivers, streams and ditches. They ganeraly perch on ground or shrubs.

57. *Orthetrum sabina* (Drury, 1770)

Size- Male: Abdomen: 30-36mm Hind wing: 30-36mm

Female: Abdomen: 32-35mm Hind wing: 31-35mm

Description: Male: Pale greenish eyes with black spots. Thorax is greenish yellow with black markings. Black coloured legs with yellow markings. Wings are transparent and the pterostigma is black. Abdomen pale greenish yellow with black

markings. Segments 7-9 are wholly black. Creamy white anal appendages have the same length of segment 9.

Female: The colouration and markings of females are similar to males.

Behaviour and habitat: Very common in forested and non forested habitats. Seen in ponds, rivers, ditches, streams, lakes, estuaries, marshes and paddy fields.

58. *Palpoleura sexmaculata* (Fabricius, 1787)

Size- Male: Abdomen: 14-16mm Hind wing: 15-21mm

Female: Abdomen: 13-14mm Hindwing: 18-21mm

Description: Male: Eyes are brown above and bluish grey beneath. Face is creamy yellow coloured. Greenish yellow coloured thorax is reddish brown on dorsum and has black and brown markings. Bright yellow coloured legs are marked with black. Wings are transparent having black markings. Hind wings have yellowish tint except at the tips. Pterostigma black with white patch. Abdomen is pale bluish and pruinosed. Anal appendages are black.

Female: Yellowish thorax is dorsally rich ochreous and with brown and black markings. Abdomen bright ochreous with a black mid dorsal stripe and broader black subsubdorsal stripes.

Behaviour and habitat: This is one of the smallest dragonflies found in Kerala. This is not commonly found. Seen around marshes and streams.

59. *Pantala flavescens* (Fabricius, 1798)

Size- Male: Abdomen: 29-35mm Hind wing: 38-40mm

Female: Abdomen: 30-33mm Hindiwng: 39-41mm

Description: Male: Eyes are reddish brown above and bluish grey beneath. Frons is bright golden yellow or orange. Thorax is olivaceous or rusty with yellow hairs. Legs are black with yellowish markings. Wings are transparent. Hind wing has golden yellow coloured base and a small brownish spot at the posterior border of the wing tip. Pterostigma is bright reddish brown. Abdomen is bright ochreous with dorsal reddish tint and black mid dorsal markings.

PLATE 10 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 10A: *Orthetrum sabina*

Figure 10B: *Palpopleura sexmaculata*

Figure 10C: *Potamarcha congener*

Figure 10D:*Rhodothemis rufa*

Figure 10E: *Rhyothemis variegata*

Figure 10F *: Tholymis tillarga*

Female: Female shows similarity with male except in some characteristics. Wings are evenly enfumed and the brownish spot is absent. The dorsal red colour of abdomen is absent.

Behaviour and habitat: This is one of the most common dragonflies. Found as swarms in open areas like paddy fields, play grounds, highways, rivers etc. This species possess highly efficient migratory capacity. Generally migrate with monsoon winds in huge numbers.

60. *Potamarcha congener* (Rambur, 1842)

Size- Male: Abdomen: 29-32mm Hind wing: 33-35mm

Female: Abdomen: 29-31mm Hind wing: 33-37mm

Description: Male: Greyish yellow coloured eyes are capped with reddish brown. Black coloured thorax is pruinosed to impart a bluish grey appearance. Legs are black. Transaprent wings, brownish at the extreme apices. Pterostigma is dark reddish brown. Abdomen is dark brown or black with medial and lateral yellow markings. Thorax and abdomen is completely pruinosed in old adults.

Female: Thorax and abdomen is dark brown in colour and marked with yellow. Segment 8 has lateral dilations.

Behaviour and habitat: This is a common species. Weedy ponds and marshes are the breeding habitats.

61. *Rhodothemis rufa* (Rambur, 1842)

Size- Male: Abdomen: 22-29mm Hind wing: 32-37mm

Female: Abdomen: 25-29mm Hind wing: 32-37mm

Description: Male: Eyes are brown capped bright red. Reddish brown coloured thorax. Legs are reddish black. Transparent wings with ochreous pterostigma. Abdomen and anal appendages are bright red.

Female: Thorax is dark brownish. Abdomen golden yellowish brown. A yellow mid dorsal stripe is present extending from prothorax to the segment 4 of abdomen.

Behaviour and habitat: Commonly found in paddy fields, rivers, ponds and estuaries.

62. *Rhyothemis variegata* (Linnaeus, 1763)

Size- Male: Abdomen: 23-25mm Hind wing: 33-36mm

Female: Abdomen: 20-22mm Hind wing: 28-37mm

Description: Male: Eyes are brownish above and grey beneath. Thorax is metallic green and the legs are black. Wings are tinted with yellow. Blackish brown patches are present at the wing tips, nodes and central area of wings. Hind wing has a large patch of yellow with blackish brown markings at the base. Abdomen is black in colour.

Female: Females vary greatly in the colour of wing from male. A large opaque area of yellow and blackish brown is present at the basal half of forewing. In hind wing opaque area of yellow and blackish brown extends the entirely except at the wing tip.

Behaviour and habitat: Common dragonfly of forested and non forested habitats. Found around paddy fields, ponds, canals, rivers and marshes. Occasionally found as small groups.

63. *Tetrathemis platyptera* (Selys, 1878)

Size- Male: Abdomen: 15-18mm Hind wing: 18-21mm

Female: Abdomen: 14-16mm Hind wing: 19-24mm

Description: Male: This is a small sized dragonfly. Eyes are bluish green coloured. Thorax is metallic black with citron yellow stripes. Legs are black. Transparent wings are tinted with amber yellow at the base of forewing and basal half of hind wing. Pterostigma black coloured. Abdomen black with citron yellow markings.

Female: Females are closely similar to males but stouter. Amber tint of wings is deeper.

Behaviour and habitat: Common species of forested and non forested habitats. Found in ponds, weedy wells and ditches. Females lay eggs during flight. Eggs are deposited on overhanging vegetation which are washed down duing rain.

64. *Tholymis tillarga* (Fabricius, 1798)

Size- Male: Abdomen: 28-33mm Hind wing: 33-37mm

Female: Abdomen: 27-31mm Hind wing: 31-37mm

Description: Male: Reddish olivaceous eyes are capped with brown. Thorax is yellowish or olivaceous laterally and bright reddish dorsally. Legs are ferruginous in colour. Wings are transparent and the hind wings have a golden brown patch and a cloudy white patch at the central portion. Abdomen is bright rusty red in colour.

Female: Head, thorax and abdomen of females are olivaceous in colour. The white patch on hind wings are absent.

Behaviour and habitat: This is a crepuscular species. Commonly found in ponds, paddy fields, streams and rivers.

65. *Tramea limbata* (Desjardins, 1832)

Size- Male: Abdomen: 33-35mm Hind wings: 44-46mm

Female: Abdomen: 32mm Hind wing: 43-46mm

Description: Male: Eyes are dark brown above and olivaceous below. Thorax is dark reddish olivaceous. Legs are black and have reddish brown shades. Transparent wings with reddish venation at the base. Hind wing has blackish brown patch at the base. Pterostigma drak brown coloured. Abdomen reddish with black rings.

Female: Females are similar to males with extensive black markings on abdomen.

Behaviour and habitat: Commonly found in forested and non forested habitats, especially around weedy ponds and marshes. Fly high during day time.

66. *Trithemis aurora* (Burmeister, 1839)

Size- Male: Abdomen: 21-29mm Hind wing: 24-34mm

Female: Abdomen: 19-27mm Hind wing: 24-31mm

Description: Male: Eyes are crimson red coloured. Reddish brown coloured face. Thorax is red in colour with purple pruinescence. Legs are black with rusty

markings. Wings are transparent with red reticulation. Wings base has an amber yellowish patch. Pterostigma is dark reddish brown. Abdomen is violaceous red in colour.

Female: Female differs from male in shape and colour. Thorax and abdomen are ochreous with black markings. Wings are brownish at apices.

Behaviour and habitat: Commonly found in forested and non forested habitats like ponds, streams, rivers, canals, marshes etc.

67. *Trithemis festiva* (Rambur, 1842)

Size- Male: Abdomen: 22-28mm Hind wing: 26-32mm

Female: Abdomen: 21-24mm Hind wing: 24-29mm

Description: Male: Bluish grey eyes are capped with purplish brown. Thorax is black and pruinosed with purple. Black coloured legs. Transparent wings. There is an opaque dark brown patch at the base of hind wing. Pterostigma is black. Abdomen is black in colour with fine yellow markings and with blue pruinescence.

Female: Thorax and abdomen are yellowish with black markings.

Behaviour and habitat: Commonly found in habitats like streams, canals and rivers. Generally, perch on rocks and twigs.

68. *Trithemis pallidinervis* (Kirby, 1889)

Size- Male: Abdomen: 28-32mm Hind wings: 30-36mm

Female: Abdomen: 26-28mm Hind wing: 30-32mm

Description: Male: Bluish grey eyes are with reddish brown cap. Frons is metallic purple on upper surface. Thorax is bright olivaceous and dorsally olivaceous brown with grey hairs. Thorax is marked with black. Legs are black and long. Transparent wings with reddish reticulation. There is an amber coloured patch at the base of wing. Pterostigma is black bordered with white at both ends. Abdomen is olivaceous and marked with black.

Female: Females show close resemblance with males. Upper surface of frons is ochreous.

PLATE 11 - ODONATES OBSERVED DURING THE STUDY (CONT.)

Figure 11A: *Tramea limbata*

Figure 11B: *Trithemis aurora*

Figure 11C: *Trithemis festiva*

Figure 11D: *Urothemis signata*

Behaviour and habitat: Commonly found in lakes, marshes and paddy fields of plains.

69. *Urothemis signata* (Rambur, 1842)

Size- Male: Abdomen: 27-28mm Hind wing: 34-37mm

Female: Abdomen: 25-27mm Hind wing: 34-36mm

Description: Male: Eyes are bright reddish above and reddish brown laterally. Thorax is blood red in colour. Legs are reddish brown or ochreous. Wings are transparent and with reddish reticulation. The base of forewing has an amber coloured small patch. The basal patch on hind wing is broader and darker. Abdomen is blood red and has dorsal black markings at the last segments.

Female: Females are yellowish coloured. All abdominal segments are dorsally marked with black.

Behaviour and habitat: Commonly found in habitats like marshes, lakes, streams, rivers, ponds and paddy fields.

70. *Zygonyx iris* (Selys, 1869)

Size- Male: Abdomen: 40-42mm Hind wings: 46-48mm

Female: Abdomen: 40-43mm Hind wing: 47-49mm

Description: Male: Eyes are dark brown above and greyish beneath. Metallic blue coloured frons. Thorax is dark metallic bluish with citron yellow markings. Legs are black. Transparent wings with blackish brown pterostigma. Abdomen in black in colour with narrow yellow markings. A large yellow spot is present at segment 7 dorsally.

Female: Females show close similarity with males but the yellow markings on abdomen are more prominent.

Behaviour and habitat: This species is common in forested habitats. Perches rarely. Found always flying over streams and brooks.

71. *Zyxomma petiolatum* (Rambur, 1842)

Size- Male: Abdomen: 37-42mm Hind wings: 32-35mm

Female: Abdomen: 37-42mm Hind wings: 32-38mm

Description: Male: Eyes are bright emerald green. Thorax is chocolate brown dorsally and paler on sides. Legs are reddish brown or ochreous. Transparent wings are tipped with brown at apices and with blackish brown pterostigma. Abdomen is chocolate brown with black rings.

Female: Females show exact resemblance with males.

Behaviour and habitat: This species is crepuscular in nature. Common in forested and non forested habitats such as ponds, wells and stagnant pools.

2.4.3 Photographic documentation of observed odonates

Phototgraphs of the observed odonates, showing the identification features were documented. The recorded photographs were displayed in Plates 3-11.

2.4.4 Molecular characterisation of selected families of odonates

Out of the observed 71 species of odonates, 34 species were selected for molecular characterisation. The selected species were coming under 10 families and 28 genera. One or two representatives of each genus were chosen for the study. Species which were characterised in previous studies (Jisha, 2018) were excluded from the present work. DNA was isolated from the specimens, the partial coding sequence of the COI gene and the partial sequence of the 18S rRNA gene were amplified using the primers given in Table 2.3.1 and 2.3.4 and they were sequenced. The sequence results were submitted to the NCBI GenBank database and received accession numbers. The accession numbers and product size are given in Table 2.4.2. The translation products of the obtained COI gene sequences were generated by using Expasy translate tool and presented in Table 2.4.3.

Table 2.4.2 Details of molecular characterization

Sl No.	Scientific Name	COI		18S rRNA	
		Accession Number	Product size	Accession Number	Product size
1.	*Lestes praemorsus*	MZ074000.1	671bp	MZ068299.1	893bp
2.	*Protosticta gravelyi*	MN974377.1	593bp	MZ882296.1	912bp
3.	*Neurobasis chinensis*	MW931875	642bp	MW931850.1	881bp
4.	*Heliocypha bisignata*	MW940786.1	676bp	MW940775.1	900bp
5.	*Libellago indica*	MW309318.1	585bp	MZ098271.1	907bp
6.	*Dysphaea ethela*	MN882704.1	677bp	MZ817954.1	925bp
7.	*Copera vittata*	MZ895506.1	691bp	MZ895795.1	905bp
8.	*Prodasineura verticalis*	MZ081640.1	701bp	MZ081546.1	902bp
9.	*Aciagrion approximans krishna*	MW246065	670bp	MZ098107.1	896bp
10.	*Agriocnemis pieris*	MN850440	627bp	OK083599.1	878bp
11.	*Agriocnemis splendidissima*	MN850441	647bp	MZ803194.1	911bp
12.	*Archibasis oscillans*	MW309421.1	617bp	MZ127377.1	909bp
13.	*Ceriagrion cerinorubellum*	MZ882339.1	690bp	MZ882369.1	906bp
14.	*Ceriagrion rubiae*	OK148120.1	346bp	OK105141.1	905bp
15.	*Ischnura rubilio*	MN850442.1	670bp	MZ809355.1	889bp
16.	*Paracercion calamorum*	MW940750.1	668bp	MZ220521.1	296bp
17.	*Paracercion malayanum*	MZ700177.1	689bp	MZ882306.1	908bp
18.	*Pseudagrion decorum*	MZ254912.1	628bp	MZ220525.1	537bp
19.	*Pseudagrion indicum*	MN882703.1	649bp	MZ817953.1	855bp
20.	*Gynacantha dravida*	MK990607.1	631bp	MZ678639.1	911bp
21.	*Gynacantha millardi*	MW649897.1	615bp	MZ145224.1	920bp
22.	*Ictinogomphus*	MW945399.1	582bp	MW940949.1	896bp

	rapax				
23.	*Diplacodes nebulosa*	MZ254913.1	555bp	MZ081547.1	904bp
24.	*Hydrobasileus croceus*	MW965658.1	671bp	MW945405.1	903bp
25.	*Onychothemis testacea*	MN803150.1	632bp	MZ803139.1	898bp
26.	*Orthetrum glaucum*	MZ087263.1	696bp	MZ081550.1	892bp
27.	*Orthetrum luzonicum*	MZ092847.1	692bp	MZ092846.1	909bp
28.	*Palpopleura sexmaculata*	OK083552.1	581bp	MZ092848.1	907bp
29.	*Rhodothemis rufa*	OK083604.1	640bp	OK083605.1	896bp
30.	*Tetrathemis platyptera*	MZ092924.1	688bp	MZ092849.1	907bp
31.	*Tholymis tillarga*	MZ127380.1	700bp	MZ093144.1	909bp
32.	*Tramea limbata*	MZ076547.1	671bp	MZ076516.1	906bp
33.	*Urothemis signata*	MZ895798.1	688bp	MZ895802.1	893bp
34.	*Zyxomma petiolatum*	MZ093432.1	677bp	MZ093372.1	912bp

Table 2.4.3 Translation products of the obtained COI gene sequences

Sl No.	Scientific Name	Translation Product
1.	*Lestes praemorsus*	>*Lestes praemorsus* isolate LPN22 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/223AA YIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWLVPLML GAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHAGASVDLTIFSLHLAGVSSILGAI NFITTTINMKSPGMKLDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAGGGDPILYQHLFW
2.	*Protosticta gravelyi*	>Protosticta gravelyi isolate PGN9 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/197AA STNHKDIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMI GGFGNWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGSIAHAGGS VDLTIFSLHLAGVSSILGAINFITTTINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGA
3.	*Neurobasis chinensis*	>Neurobasis chinensis isolate NCN16 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/214AA LTLYLLFGAWAGMVGTALSMIIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGNWL VPLMLGAPDMAFPRLNNMSFWLLPPALTILMASSLVESGAGTGWTVYPPLASGLGHPGGSVDLTIFSL HLAGVSSILGAINFITTTINMKTPGMKMDQMPLLVWAVLITAVLLLLSLPVLAGAITMLLTDRNMNTSF FDPAGGGDPI
4.	*Heliocypha bisignata*	>Heliocypha bisignata isolate HBN18 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/224AA HKDIGTLYLLFGAWAGMAGTALSMLIRVELGQPGTLIGDDQIYNVVVTAHAFIMIFFMVMPIMIGGFGNWLVPL MLGAPDMAFPRMNNMSFWLLPPSLTLLLSSSLVESGAGTGWTVYPPLAGAIAHAGGSVDLTIFSLHLAGVSSILG AINFITTTINMKPPGMKMDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAGGGDPILYQHLF
5.	*Libellago indica*	>Libellago indica isolate LIN12 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/194AA TALSMLIRVELGQPGTLIGDDQIYNVVVTAHAFIMIFFMVMPIMIGGFGNWLVPLMLGAPDMAFPRMN NMSFWLLPPSLSLLLSSSLVESGAGTGWTVYPPLAGAIAHAGGSVDLTIFSLHLAGVSSILGAINFITTTI NMKAPGMKMDQMPLFVWAVIITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAG
6.	*Dysphaea ethela*	>Dysphaea ethela isolate DEN8 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/225AA IGTLYLMFGAWAGMVGTALSMLIRIELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGNWL VPLMLGAPDMAFPRLNNMSFWLLPPSITLLLTSSLVESGAGTGWTVYPPLAGAIAHAGGSVDLTIFSLH LAGVSSILGAINFISTTINMKTPGMKMDQMPLFVWAVVITALLLLLSLPVLAGAITMLLTDRNINTSFFD PAGGGDPILYQHLFWFFG

7.	*Copera vittata*	>Copera vittata isolate CVN33 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/230AA HKDIGTLYLMFGAWAGMVGTALSMLIRIELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFG NWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHSGGSVDLTI FSLHLAGVSSILGAINFITTTINMKSPGMSMDQMPLFVWAVIITAVLLLLSLPVLAGAITMLLTDRNINTS FFDPAGGGDPILYQHLFWFFGHW
8.	*Prodasineura verticalis*	>Prodasineura verticalis isolate PVN24 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/233AA STNHKDIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMI GGFGNWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGSIAHAGGS VDLTIFSLHLAGVSSILGAINFITTTINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTD RNINTSFFDPAGGGDPILYQHLFWFFGHP
9.	*Aciagrion approximans krishna*	>Aciagrion approximans krishna isolate AAKN11 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/223AA YLMIGAWAGLVGTALSMLIRIELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGNWLVPLM LGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLASVIAHAGASVDLTIFSLHLAG VSSILGAINFITTTINMKSPGMNMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAG GGDPILYQHLFWFFGHP
10.	*Agriocnemis pieris*	>Agriocnemis pieris isolate APN3 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/208AA KDIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFG NWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHGGGFVDLT IFSLHLAGVSSILGAINFITTTINMKSPGMKLEQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINT SFF
11.	*Agriocnemis splendidissima*	> Agriocnemis splendidissima isolate ASN4 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/215AA IGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGNW LVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLASAIAHAGASVDLTIFSL HLAGVSSILGAINFITTTINMKSPGMKMEQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFF DPAGGGDPI
12.	*Archibasis oscillans*	>Archibasis oscillans isolate AON13 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/205AA GMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGNWLVPLMLGAPDMA

		FPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHAGGSVDLTIFSLHLAGVSSILGAIN FITTTINMKSPGMKMDQMPLFVWAVIITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAGGGDPILY
13.	*Ceriagrion cerinorubellum*	>Ceriagrion cerinorubellum isolate CCN32 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/221AA HKDIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGF GNWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHAGGSVDL TIFSLHLAGVSSILGAINFITTVINMKSPGMKLDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNIN TSFFDPAGGGDPILYQHLFWFFGHQ
14.	*Ceriagrion rubiae*	>Ceriagrion rubiae isolate CRN36 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/115AA IGSPPPAGSKNDVLMFRSVNNMVMAPANTGNDNNNNTAVITTAHTNSGNWSSFIPGDFMLITVVMKLI APKIEDTPAKCNEKIVSSTDPPACAIAPASGGYTVQPVPAPLSTKLL
15.	*Ischnura rubilio*	>Ischnura rubilio isolate IRN5 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/223AA HKDIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGF GNWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGVIAHAGASVDL TIFSLHLAGVSSILGAINFITTTINMKSPGMNMDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNI NTSFFDPAGGGDPILYQHL
16.	*Paracercion calamorum*	>Paracercion calamorum isolate PCN17 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/222AA YIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGN WLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHAGGSVDLTIF SLHLAGVSSILGAINFITTTINMKSPGMKMDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTS FFDPAGGGDPILYQHLF
17.	*Paracercion malayanum*	>Paracercion malayanum isolate PMN15 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/229AA NKDIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGF GNWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHAGGSVDL TIFSLHLAGVSSILGAINFITTTINMKSPGMKMDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNI NTSFFDPAGGGDPILYQHLFWFFGH
18.	*Pseudagrion decorum*	>Pseudagrion decorum isolate PDN21 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/209AA TLYLMFGAWAGMVGIALSMLIRVELGQPGSLIGGDQIYNVVVTVHAFVMIFFMFMLIMIGGFGNWVV

		PLMLGAPDMAFPRLNNMSFWLLPPSLMLLLASSLVESGAGMGWTVYPPLAGAVAHAGGSVNLTVFS LHLGGVSSILGAINCITTTINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDGNINTS FFDPAGV
19.	*Pseudagrion indicum*	>Pseudagrion indicum isolate PDN21 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/216AA YIGTLYLMFGAWAGMVGTALSMLIRVELGQPGSLIGDDQIYNVVVTAHAFVMIFFMVMPIMIGGFGN WLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLASSLVESGAGTGWTVYPPLAGAIAHAGGSVDLTIF SLHLAGVSSILGAINFITTTINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTS FFDPAGGGDPI
20.	*Gynacantha dravida*	>Gynacantha dravida isolate GDN1 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/209AA RSTNHKDIGTLYFLFGAWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIG GFGNWLVPLMLGAPDMAFPRLNNMSFWLLPPSLTLLLAGSMVESGAGTGWTVYPPLAGAIAHAGAS VDLTIFSLHLAGVSSILGAINFITTTINMKSPGMKLDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTD RNIN
21.	*Gynacantha millardi*	>Gynacantha millardi isolate GBN14 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/205AA AWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWLVPLMLGAPD MAFPRLNNMSFWLLPPSLTLLLAGSMVESGAGTGWTVYPPLAGAIAHAGASVDLTIFSLHLAGVSSIL GAINFITTTINMKSPGMKLDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAGGGDP
22.	*Ictinogomphus rapax*	>Ictinogomphus rapax isolate IRN19 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/193AA VGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWLVPLMLGAPDMAFPRM NNMSFWLLPPSLTLLLASSMVESGAGTGWTVYPPLAGAIAHARGSVDFTIFSIHLAGVSSILGAINFITT TINMKFPGMSMEQMPLFVWAVLITAVLLMLSLPVLAGAITMLLTDRNLNTSFFD
23.	*Diplacodes nebulosa*	>Diplacodes nebulosa isolate IRN19 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/184AA LYLIFGAWAGMIGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWLVPLM LGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGAIAHAGASVDLTIFSLHLAG VSSILGAINFITTVINMKSPGMKLDQMPLFVWAVVITAVLLLLSLPV
24.	*Hydrobasileus croceus*	>Hydrobasileus croceus isolate IRN19 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/223AA KDIGTLYLIFGAWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNW LVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGAIAHAGASVDLTIFS LHLAGVSSILGAINFITTVINMKSPGMTLDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFF

		DPAGGGDPILYQHLF
25.	*Onychothemis testacea*	>Onychothemis testacea isolate OTN2 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/210AA QQNHKDIGTLYLIFGAWAGMIGTALSVLIRVELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGG FGNWLVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLSSSLVESGAGTGWTVYPPLAGAIAHAGASVD LTIFSLHLAGVSSILGAINFITTVINMKSPGMKLDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRN INTS
26.	*Orthetrum glaucum*	>Orthetrum glaucum isolate OGN26 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/232AA HKDIGTLYLIFGAWAGMIGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNW LVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGAIAHAGASVDLTIFS LHLAGVSSILGAINFITTVINMKSPGMKLDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSF FDPAGGGDPILYQHLFWFFGHPEV
27.	*Orthetrum luzonicum*	>Orthetrum luzonicum isolate OLN27 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/230AA HKDIGTLYLIFGAWAGMIGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNW LVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLTSSMVESGAGTGWTVYPPLAGAIAHAGASVDLTIFS LHLAGVSSILGAINFITTVINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTS FFDPAGGGDPILYQHLFWFFGHP
28.	*Palpopleura sexmaculata*	>Palpopleura sexmaculata isolate PSN28 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/193AA GQQNHKDIGTLYLIFGAWAGMIGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGG FGNWLLPLMLGPPDMAFPRVNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGGIAHAGASVD LTIFSLHLASVSSILGAINFITTVITMKSPGMKLDQLPLFVWAVLITAVLLLLSLP
29.	*Rhodothemis rufa*	>Rhodothemis rufa isolate RRN34 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/213AA WTLYLVFGAWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWLV PLMLGAPDMAFPRLNNMSFWLLPPSFTLLLSSSLVESGAGTGWTVYPPLAGAIAHAGASVDLTIFSLHL AGVSSILGAINFITTVINMKSPGMKLDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFFDP AGGGDP
30.	*Tetrathemis platyptera*	>Tetrathemis platyptera isolate TPN29 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/229AA YIGTLYLIFGAWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWL VPLMLGAPDMAFPRMNNMSFWLLPPSFTLLLASSIVESGAGTGWTVYPPLAGAIAHAGASVDLTIFSL

		HLAGVSSILGAINFITTVINMKSPGMKMDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFF DPAGGGDPILYQHLFWFFGHPG
31.	*Tholymis tillarga*	>Tholymis tillarga isolate TTN30 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/233AA NHKDIGTLYFIFGAWAGMIGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGN WLVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGGIAHAGASVDLTI FSLHLAGVSSILGAINFITTVINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNIN TSFFDPAGGGDPILYQHLFWFFGHPEV
32.	*Tramea limbate*	>Tramea limbata isolate TLN23 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/223AA LTLYLIFGAWAGMIGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGNWLVPL MLGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGAIAHAGASVDLTIFSLHLA GVSSILGAINFITTVINMKSPGMSIDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTSFFDPAG GGDPILYQHLFWFF
33.	*Urothemis signata*	>Urothemis signata isolate USN35 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/229AA HKDIGTLYLIFGAWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPIMIGGFGN WLVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGAIAHAGASVDLTI FSLHLAGVSSILGAINFITTVINMKSPGMSLDQLPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNINTS FFDPAGGGDPILYQHLFWFFGH
34.	*Zyxomma petiolatum*	>Zyxomma petiolatum isolate ZPN31 cytochrome c oxidase subunit I (COX1), partial(mitochondrial)/225AA KDIGTLYLIFGAWAGMVGTALSVLIRIELGQPGSLIGDDQIYNVIVTAHAFVMIFFMVMPVMIGGFGN WLVPLMLGAPDMAFPRLNNMSFWLLPPSFTLLLASSMVESGAGTGWTVYPPLAGAIAHAGASVDLTI FSLHLAGVSSILGAINFITTVINMKSPGMKMDQMPLFVWAVVITAVLLLLSLPVLAGAITMLLTDRNLN TSFFDPAGGGDPILYQHLFWL

2.4.5 NOVEL RECORDS OF THE PRESENT WORK

Of the 34 species characterised, COI gene sequence records of 12 species and 18S rRNA gene sequence records of 23 species were the novel GenBank records. While considering the remaining records, COI gene sequences of 8 species and 18S gene sequences of 6 species are the first records from India. The pioneer records from Kerala are twelve COI and five 18S rRNA gene sequences. Sequences of *Onychothemis testacea* are the first GenBank records of the corresponding genus of both genes. The details of the novel records are given in Table 2.4.4.

Table 2.4.4: Novel GenBank records of the present work

Sl No.	Name of species	GenBank	India	Kerala
1.	*Lestes praemorsus*	18S rRNA	COI	
2.	*Protosticta gravelyi*	COI & 18S rRNA		
3.	*Neurobasis chinensis*			COI & 18S rRNA
4.	*Heliocypha bisignata*	18S rRNA		
5.	*Libellago indica*	COI & 18S rRNA		
6.	*Dysphaea ethela*	18S rRNA		COI
7.	*Copera vittata*		18S rRNA	COI
8.	*Prodasineura verticalis*	18S rRNA		COI
9.	*Aciagrion approximans krishna*	COI & 18S rRNA		
10.	*Agriocnemis pieris*	COI & 18S rRNA		
11.	*Agriocnemis splendidissima*	COI & 18S rRNA		
12.	*Archibasis oscillans*	18S rRNA		
13.	*Ceriagrion cerinorubellum*			COI & 18S rRNA
14.	*Ceriagrion rubiae*	COI & 18S rRNA		
15.	*Ischnura rubilio*		18S rRNA	
16.	*Paracercion calamorum*		COI	18S rRNA
17.	*Paracercion malayanum*		COI & 18S rRNA	
18.	*Pseudagrion decorum*	COI		18S rRNA
19.	*Pseudagrion indicum*	COI & 18S rRNA		
20.	*Gynacantha dravida*	COI & 18S rRNA		
21.	*Gynacantha millardi*	COI & 18S rRNA		
22.	*Ictinogomphus rapax*	18S rRNA	COI	
23.	*Diplacodes nebulosa*	18S rRNA		COI
24.	*Hydrobasileus croceus*		COI & 18S rRNA	
25.	*Onychothemis testacea*	COI & 18S rRNA		
26.	*Orthetrum glaucum*		18S rRNA	COI
27.	*Orthetrum luzonicum*		COI	18S rRNA
28.	*Palpopleura sexmaculata*	18S rRNA		COI
29.	*Rhodothemis rufa*	18S rRNA	COI	
30.	*Tetrathemis platyptera*	18S rRNA		COI
31.	*Tholymis tillarga*	18S rRNA		COI
32.	*Tramea limbata*	18S rRNA		COI
33.	*Urothemis signata*	18S rRNA	COI	
34.	*Zyxomma petiolatum*		18S rRNA	COI

2.5 DISCUSSION

The odonate fauna of Kerala is well studied. The number of people interested in odonate studies is increasing day by day and the contributions of odonatologists along with other scientific works nourish the odonate literature of Kerala. Although most of the works are sporadic, the works of Kiran and Raju (2013), Nair et al. (2021) and Gopalan et al. (2022) have provided a summarized picture on odonates of Kerala. According to Gopalan et al. (2022), there are 174 species in Kerala (74 damselflies and 100 dragonflies), in comparison to 71 species (33 species of damselflies and 38 species of dragonflies), recorded in the present study which was confined to 5 districts of Kerala and excluded the protected areas. Diversity is highest at pristine forested habitats especially in montane forests. Most of the endemics are restricted to the streams and rivers of untouched forests (Subramanian and Babu, 2007; Subramanian et al., 2008; Sureshan et al., 2022). As the present study was concentrated mainly on human inhabited habitats the species list was dominated by generalist species. The Western Ghats endemic species recorded during the study are *Aciagrion approximans krishna, Agriocnemis keralensis, Pseudagrion indicum* and *Protosticta gravelyi.* The rarely encountered species *Paracercion malayanum* is the first record from central and northern Kerala. Nair et al. (2021) has reported this species as personal record of Bo Nielson from Agasthyamalais landscape only.

During the present survey species richness of dragonflies was more than that of damselflies. A total of 38 species of dragonflies were recorded, which constitute 54% of the total species recorded during the study. Number of damselfly species found was 33 which comprises 46% of the total species found. Findings of other workers (Adarsh et al., 2014; Kulkarni and Subramanian, 2013; Tiple et al., 2013) match with this result that, dragonflies are more diverse and dominant over damselflies. Dragonflies are highly specialized for wide range habitat tolerance and possess high dispersal ability (Williams,1997; Lawler, 2001; Suhling et al.,2004; 2005; Saha, 2015). This can be the reason for increased species richness and abundance of dragonflies. In contrast to this, fragile body, weak flight capacity, limited dispersal ability and requirement of shade cover may be the reason for decreased abundance of damselflies (Weir, 1974; Williams, 1997; Clark and Samways, 1996).

The locations for the survey were randomly selected to include various habitats ranging from sea level to hilly areas. The habitats selected for the present study included ponds, rivers, lakes, canals, paddy fields, coastal marshes and streams. A total of 71 species belonging to 44 genera and 10 families were recorded during the survey. 33 species of damselflies of 17 genera which are the representatives of 7 families of Zygoptera viz. family Lestidae, Platystictidae, Calopterygidae, Chlorocyphidae, Euphaeidae, Platycnemididae, Coenagrionidae were recorded. The most dominant family and genus of damselflies observed were Coenagrionidae and *Pseudagrion* respectively. The rarely found species were *Protosticta gravelyi, Paracercion malayanum* and *Ceriagrion rubiae* which were found only once in single location. 38 species of dragonflies belonging to 27 genera and 3 families (Aeshnidae, Gomphidae and Libellulidae) were encountered during the survey. Members of the genus *Orthetrum* were dominant during the study. Representatives of family Libellulidae were abundantly seen. The dominance of families Coenagrionidae and Libellulidae was supported by a good number of literature (Arunima and Nameer, 2021; Bose et al., 2021; Chandran et al., 2021; Subramanian et al., 2008; Kulkarni and Subramanian, 2013).

The observed species richness was high in vegetated ponds, lakes and streams and was minimum in unvegetated habitats. Native vegetation supported maximum odonate diversity (Bose et al., 2021; Lozano et al., 2022). Habitats with rich shade cover showed maximum damselfly diversity and this finding was in agreement with Arulprakash & Gunathilagaraj (2010). While dragonflies were abundantly found in sunny biotopes which were in congruence with the result of Remsburg (2008), Corbet (1999), Samways and Steytler (1996).

Out of the observed 71 species, 34 species were selected for molecular characterisation. Previously studied species were excluded from the present study (Krishnan, 2018). Partial mitochondrial COI gene sequence and nuclear 18S rRNA gene sequence of 34 species of odonates were sequenced and submitted to the GenBank database. Out of the 34 COI gene sequences, 12 are the first GenBank records of the corresponding species, 8 are the pioneer records from India and 12 are the first records from Kerala. While considering the 34 sequences of 18S rRNA gene, 23 are pioneer records of GenBank, 6 are first records from India and 5 are

first from Kerala. The partial COI and 18S rRNA gene sequences of *Onychothemis testacea* are the first GenBank records of the corresponding genus.

Most of the COI sequences have good product sizes of more than 600bp length and 18S rRNA sequences have more than 850bp length. All the generated amino acid sequences did not have internal stop codons and the quality of the sequences was confirmed by an uninterrupted open reading frame. Mitochondrial COI sequences can be used for precise and faster identification of odonate species and phylogenetic studies. Nuclear 18S rRNA gene sequences will be useful in phylogenetic analysis at different taxonomic levels. (Carle et al., 2008; Dumont et al., 2010; Huang et al., 2020).